Appointment

From: Nelson, Brian [nelson.brian@epa.gov]
Sent: 3/18/2019 9:02:33 PM
To: Grundler, Christopher [grundler.christopher@epa.gov]

Subject: Fw: Social Event with USEPA Staff

Start: 3/28/2019 1:00:00 AM
End: 3/28/2019 4:00:00 AM
Show Time As: Tentative

Recurrence: (none)

From: Galgani, Kelcie@ARB
Sent: Wednesday, February 27, 2019 1:37 PM
To: Galgani, Kelcie@ARB; Nelson, Brian
Subject: Fw: Social Event with USEPA Staff
When: Wednesday, March 27, 2019, 9:00 PM to Thursday, March 28, 2019, 12:00 AM.
Where:

Kim A. Heroy-Rogalski, P.E.
Chief
Mobile Source Regulatory Development Branch
(916) 327-2200

From: Galgani, Kelcie@ARB
Sent: Monday, February 25, 2019 1:12 PM
To: Galgani, Kelcie@ARB; Heroy-Rogalski, Kim@ARB; Kitowski, Jack@ARB; Cliff, Steve@ARB; Carter, Michael@ARB
Cc: Robertson, Bill@ARB
Subject: Social Event with USEPA Staff
When: Wednesday, March 27, 2019 6:00 PM-9:00 PM.
Where:

Appointment

From: Galgani, Kelcie@ARB [Kelcie.Galgani@arb.ca.gov]
Sent: 3/18/2019 9:02:34 PM
To: Galgani, Kelcie@ARB [Kelcie.Galgani@arb.ca.gov]; Grundler, Christopher [grundler.christopher@epa.gov]; Nelson, Brian [nelson.brian@epa.gov]

Subject: Fw: Social Event with USEPA Staff

Start: 3/28/2019 1:00:00 AM
End: 3/28/2019 4:00:00 AM
Show Time As: Tentative

Recurrence: (none)

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Cc: Robertson, Bill@ARB
Subject: Social Event with USEPA Staff
When: Wednesday, March 27, 2019 6:00 PM-9:00 PM.
Where:

Message

From: grundler.christopher@epa.gov [grundler.christopher@epa.gov]
Sent: 4/29/2019 10:41:11 PM
To: Richard Corey [richard.corey@arb.ca.gov]; Steve.Cliff@arb.ca.gov
Subject: Fwd: New Report Highlights Major Concerns With Trump GHG Vehicle Emissions Proposal
Attachments: FINALPRESSRELEASE.docx; ATT00001.htm; FINALGHGREPORT.PDF; ATT00002.htm

FYI, this just came to me. Richard and I recently spoke Deliberative Process / Ex. 5 Deliberative Process / Ex. 5 Attached press release Deliberative Process / Ex. 5

Chris

Christopher Grundler, Director
Office of Transportation and Air Quality
U.S. Environmental Protection Agency
202.564.1682 (Washington DC)
734.214.4207 (Ann Arbor MI)
734.645.5221 (mobile)
www.epa.gov/otaq

Begin forwarded message:

> **From:** Bill Becker <bbecker744@comcast.net>
> **Date:** April 29, 2019 at 5:19:47 PM EDT
> **To:** "Grundler.Christopher@epamail.epa.gov" <Grundler.Christopher@epamail.epa.gov>
> **Subject: New Report Highlights Major Concerns With Trump GHG Vehicle Emissions Proposal**
>
> Chris—fyi
>
> I am happy to provide you with our report, released today, on the impacts of the Trump proposal to weaken vehicle GHG emissions standards. The report, *The Devastating Impacts of the Trump Proposal to Roll Back Greenhouse Gas Emissions Standards*, analyzes the rule's non-GHG emissions impacts, including smog-forming emissions, fine particles, and air toxins. Our "untold story" concludes that 1) up to 32,000 people could die prematurely and millions more get sick, 2) state and local agencies' compliance with the Clean Air Act will be severely undermined, and 3) businesses will have difficulties expanding their operations.
>
> I have attached a copy of the report and a press release and include a link to the report below.
>
> Feel free to contact me if you have any questions.

Bill Becker
(Former Executive Director of the National Association of Clean Air Agencies)

https://documentcloud.adobe.com/link/track?uri=urn%3Aaaid%3Ascds%3AUS%3A72b78935-2ee6-4341-a986-8631c70f3505

Bill Becker
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301-806-6111

THE DEVASTATING IMPACTS OF THE TRUMP PROPOSAL TO ROLL BACK GREENHOUSE GAS VEHICLE EMISSIONS STANDARDS

"THE UNTOLD STORY"

WRITTEN BY

S. WILLIAM BECKER AND MARY D. BECKER

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THE DEVASTATING IMPACTS OF THE TRUMP PROPOSAL TO ROLL BACK GREENHOUSE GAS VEHICLE EMISSIONS STANDARDS*

"The Untold Story"

I. EXECUTIVE SUMMARY

In August 2018, the Trump Administration proposed the Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021-2026 Passenger Cars and Light Trucks, which significantly weakens the existing federal motor vehicle fuel economy and greenhouse gas (GHG) emissions standards in two substantial ways: 1) it rolls back the progressively more stringent existing federal vehicle emissions standards, freezing them at the Model Year 2020 level; and 2) it proposes to revoke California's waiver of federal preemption that has allowed California (and other states that opt into California's program) to adopt and enforce the more stringent emissions standards they deem essential for healthy air quality.

Weakening the existing GHG emissions standards and revoking California's waiver of federal preemption will cause huge adverse impacts on society. In particular, it will create disturbing consequences for 1) public health, including increased mortality and morbidity; 2) states' compliance with the Clean Air Act; and 3) industrial operations, such as limiting the ability of businesses to build new facilities or expand existing ones.

While many stakeholders have analyzed the adverse effects the proposed rule will have on climate change and GHG emissions, we focus, instead, on the "untold story" of the devastating

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* Written by S. William Becker and Mary D. Becker. Bill is President of Becker Environmental Consulting. He has worked on environmental issues since 1972 and retired in June 2017 after serving as the Executive Director of the National Association of Clean Air Agencies for 37 years. Mary is an environmental attorney who has worked on environmental law and policy issues for the past 38 years in private practice, at the Environmental Law Institute, and as president of her own consulting company.

impacts from substantial increases in *non-GHG emissions*, including smog-forming emissions, fine particles, sulfur oxides and toxic air pollution.

In our report, we highlight the Trump Administration's flawed assessments, inaccurate technical and economic assumptions, modeling errors and incomplete analysis. We conclude that after correcting these key errors, the following devastating impacts will occur if the SAFE Vehicles rule is adopted:

- Millions of people throughout the United States will either die prematurely or develop preventable serious illnesses.
    - Up to 32,000 people nationwide will die prematurely just from the anticipated increases in fine particles.
    - Millions of others are expected to develop serious illnesses, including, but not limited to, respiratory illness, asthma exacerbation, heart attacks, and minor restricted activity days.
    - These harmful health effects will be felt in every state in the country. In some states, including California, Florida, New York, Ohio, Pennsylvania, and Texas, the expected impacts are especially disturbing. In the Appendix we have tables quantifying the mortality and morbidity impacts nationwide and for each of the 48 contiguous states and Washington, D.C.
- States' compliance with the Clean Air Act will be severely undermined in several important ways.
    - State and local regulatory agencies have developed State Implementation Plans that rely on emissions reductions from the existing motor vehicle control program. To the extent the existing program is weakened by rolling back and freezing the federal emissions standards and revoking California's waiver authority, state strategies may no longer be able to demonstrate they are on a path toward clean air.
    - States not able to comply with the CAA as a result of the weakened vehicle standards could face mandatory economic sanctions, such as the loss of millions of dollars in federal grants for building highways and a penalty (2:1 offset requirement) that is akin to a construction ban.
    - Regulatory agencies will be required to search for alternative and less cost-effective strategies to make up for lost vehicle emissions reductions from the weakened proposal.

- Attainment of the health-based air quality standards could be delayed in over a dozen areas within reach of the standards, including Baltimore, MD, Cleveland, Cincinnati, and Columbus, OH, Detroit, MI, Louisville, KY, Milwaukee, WI, San Antonio, TX, San Francisco, CA, Yuma, AZ, and Washington, DC.

- Over 200 counties in 40 states that are currently meeting one or more of the health-based air quality standards could be in jeopardy of violating the standards, triggering an array of stringent measures for their communities and businesses.

- Businesses will face serious impacts as a result of the expected increases in emissions.

  - To make up for the loss of emissions reductions expected from the existing vehicle emissions standards, sources that have already installed pollution controls may be required to retrofit with *additional* controls, which are often costlier and less efficient. Seeking additional reductions from these sources creates equity issues and undermines those businesses that have acted in good faith.

  - Small "mom and pop" sources, such as bakeries, dry cleaners, and auto body shops, may be required to install pollution controls for the first time and be required to obtain emissions "offsets."

  - Companies may be loath to locate in areas if there is uncertainty as to what controls they will have to employ to meet their air quality permitting requirements.

In conclusion, we have determined that the Safe Vehicles rule is so severely flawed that it must be rescinded. Even with the potential modest improvements that have been reported in the trade press, we can still expect the proposal to have deeply troubling impacts on public health, states' compliance with the Clean Air Act, and business operations.

II. BACKGROUND AND HISTORY

A. *The Role of the Federal Government*

The federal government has imposed fuel economy standards on vehicle manufacturers since the mid-1970s. During the OPEC oil embargo of 1973-1974 crude oil prices tripled, fuel prices skyrocketed and fuel shortages produced long, frustrating lines at the pump. Congress recognized that passenger cars and trucks had to become more fuel efficient to begin to cut back on America's dependence on foreign oil.

In 1975, Congress passed the Energy Policy and Conservation Act (EPCA), which authorized the National Highway Traffic Safety Administration (NHTSA) to promulgate regulations for and enforce Corporate Average Fuel Economy (CAFE) standards for passenger cars and light trucks.[1] The CAFE standards set a "miles-per-gallon" (mpg) target that each automaker had to achieve for its entire fleet of vehicles for each model year. NHTSA raised the targets over time, although the standards remained fairly stagnant for passenger cars from the mid-1980s until 2011, when Congress required a gradual tightening of the standards pursuant to the Energy Independence and Security Act of 2007 (EISA).[2] EISA set a target of 35 mpg for cars and light trucks for Model Year 2020, with interim standards set to begin in Model Year 2011. The legislation brought medium- and heavy-duty trucks into the fuel economy program for the first time. EISA provided flexibility for the automakers, who could earn credits for over-compliance that could be applied to another vehicle class not meeting the standard or bought and sold between manufacturers.

The major impetus for NHTSA's CAFE fuel economy targets under EPCA was to reduce America's dependence on foreign oil. The Environmental Protection Agency's (EPA's) focus, however, was to protect air quality.

The CAA of 1970 directed EPA to establish health-based air quality standards -- National Ambient Air Quality Standards (NAAQS)—for six relatively common air pollutants known as "criteria pollutants," including those emitted from vehicles: nitrogen dioxide (NO_2), ozone (formed from precursor pollutants such as nitrogen oxides (NO_x) and volatile organic compounds (VOCs)), sulfur dioxide (SO_2), lead, and particulate matter (PM).[3] The primary, or health-based, standards had to be set at levels necessary "to protect the public health" with an "adequate margin of safety."[4] If an area of the country exceeds the NAAQS for at least one pollutant, it is considered to be in "nonattainment," which triggers mandatory requirements for regulatory agencies and communities, including businesses. New facilities are required to

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[1] Energy Policy and Conservation Act (EPCA) (P.L. 94-163).

[2] Energy Independence and Security Act of 2007 (EISA) (P.L. 110-140). EISA was a broad energy law that amended EPCA and also set standards for appliance and lighting energy efficiency and renewable fuels.

[3] Clean Air Act of 1970, as amended, 42 U.S.C. §7409.

[4] 42 U.S.C. §7409(b). Secondary standards are set at levels necessary to protect public welfare from "any known or anticipated effects associated with the pollutant," including effects on vegetation, crops, wildlife, buildings and national monuments, and visibility.

install the most stringent pollution control equipment and abide by operational limits. Existing sources may be required to retrofit, take limits on production, or find offsets to expand their production. The CAA requires states with areas in nonattainment to develop plans (called State Implementation Plans (SIPs)) that include all the strategies they will use to achieve compliance with the NAAQS by statutory deadlines.

Congress recognized that motor vehicle emissions were a major source of air pollutants and authorized EPA to establish national vehicle emissions standards for new motor vehicles that "cause, or contribute to, air pollution which may reasonably be anticipated to endanger public health or welfare."[5] Vehicle emission standards and their projected reductions are important components of SIPs. Thus, motor vehicle tailpipe emission standards have played a critical role in state efforts to achieve and maintain the health-based NAAQS for nearly half a century.

B. *The Role of California*

Another major player in the establishment of motor vehicle standards is the state of California, which has long been recognized as the preeminent leader in the research and development of vehicle emissions regulations. California established the first tailpipe emissions standards in the United States in 1966, even before the passage of the 1967 federal Air Quality Act.[6] When Congress authorized EPA to regulate motor vehicle emissions in the CAA of 1970, it preempted the states from imposing their own requirements, with one notable exception.[7] Recognizing and acknowledging California's unique expertise and technical experience in developing vehicle emissions standards, Congress allowed any state that had established its own state-level emissions standards prior to March 30, 1966 (i.e., California) to ask EPA for a waiver from preemption as long as its standards are as protective as those of the federal government.[8] California has filed over 100 waiver applications requesting either confirmation of its authority to impose new emissions standards or a determination that regulatory changes fall within the scope of an existing waiver.[9] Since 1976, all but one of those waiver requests have been granted by both Republican and Democratic administrations.

Under the CAA's preemption provision, California was the only state that could write its own vehicle emissions standards. In 1977, however, Congress recognized the success of the California vehicle emissions control program, and allowed, under Section 177 of the CAA, other

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[5] Clean Air Act §202(a), 42 U.S.C. §7521(a).

[6] The 1966 California regulations adopted standards for carbon monoxide (CO) and hydrocarbon (HC) emissions.

[7] Clean Air Act §209(b), 42 U.S.C. §7543(b).

[8] Pursuant to changes in the CAA of 1977, the EPA Administrator *must* grant any request by California for a waiver of federal preemption for state standards unless he/she makes a finding that 1) California's determination of protectiveness is arbitrary or capricious; 2) the regulations are inconsistent with federal standards and enforcement procedures; or 3) that California does not need more stringent standards to meet "compelling and extraordinary conditions." 42 U.S.C. §7543(b). Thus, the burden is on those opposing the waiver to demonstrate that the three criteria for denial have been met.

[9] The U.S. Department of Health, Education and Welfare approved California's first waiver in July 1968 for emission standards beginning in Model Year 1969.

states to "opt in" to and adopt approved California standards.[10] These states, known as Section 177 states, can adopt California's more stringent standards (without changes) and can do so without explicit EPA approval. The Act specifies that only states with nonattainment areas can adopt and enforce California's standards. Congress recognized that these states may need the more stringent emissions standards to achieve compliance. This "opt-in" provision has allowed other states the ability to use California's innovative and more protective vehicle emissions control strategies to help meet the federal health-based NAAQS.

It is impossible to overestimate the importance of the California waiver provision in the Clean Air Act to the states. California's ability to set its own vehicle emissions standards—and the right of other states to follow when needed—is the insurance policy, the "tool in the tool box," the states need in the event the federal government is unable or unwilling to set national standards that adequately address the states' air pollution control needs. While some stakeholders advocate for a uniform, 50-state vehicle emissions control program, it is paramount that California retain its statutory authority under Section 209 of the CAA to set and enforce its own standards where the state deems it necessary and that other states retain their statutory authority under Section 177 of the Act to follow suit to protect air quality and public health.

C. *Regulation of Greenhouse Gas Emissions*

While EPA clearly has authority over air pollutants directly contributing to smog and dirty air harmful to health and welfare, its authority to regulate carbon dioxide (CO_2) and other GHG emissions under the CAA was less clear and contested for many years. This changed beginning in 2007, when the Supreme Court ruled that GHGs fit within the definition of "air pollutant" under the CAA[11] and could be regulated if EPA determined that GHGs "caused or contributed" to air pollution endangering public health and welfare, as required by the Act. In 2009, EPA found that GHGs do indeed threaten public health and welfare and that GHGs from new motor vehicle emissions contribute to that pollution.[12] This "endangerment finding" meant that GHG emissions leading to climate change could be regulated for the first time by the federal government under the CAA. Following this finding, in May 2009, President Obama directed NHTSA and EPA to work together to harmonize and streamline the federal CAFE standards and the GHG tailpipe standards[13] and negotiations with vehicle manufacturers, California and other states, and unions, as well as other major stakeholders began.

Meanwhile, California had been moving ahead with research and development of GHG vehicle emission regulations since 2002.[14] In 2004 California promulgated regulations requiring GHG

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[10] 42 U.S.C. §7507.

[11] *Massachusetts v. EPA*, 549 U.S 497, 528-29 (2007).

[12] EPA, "Endangerment and Cause or Contribute Findings for Greenhouse Gases under Section 202(a) of the Clean Air Act; Final Rule," 74 *Federal Register* 66496, December 15, 2009.

[13] "President Obama Announces National Fuel Efficiency Policy," The White House, May 19, 2009.

[14] The California legislature mandated the California Air Resources Board (CARB) in 2002 to develop regulations reducing GHG emissions in noncommercial vehicles (Assembly Bill 1493). CARB promulgated those regulations

emissions reductions for vehicles manufactured in Model Year 2009 and after. The state's request for a waiver of federal preemption was initially denied by EPA under the Bush Administration, which determined that climate change impacts did not produce "compelling and extraordinary conditions" specific to California.[15] When President Obama came into office, however, EPA reversed the decision and granted California its waiver in 2009.[16]

The EPA Administrator found that the CAA gives California broad leeway to determine what emissions standards are appropriate for its motor vehicle program to protect its residents from pollution problems.[17] EPA found that the opponents of the waiver had not rebutted California's analysis that climate change impacts were creating compelling and extraordinary conditions in California, as was their burden to do.[18] Significantly, the California Air Resources Board (CARB) had also shown that its GHG standards would reduce upstream emissions of criteria and toxic air pollutants (i.e., emissions generated by the production and transport of fuel) due to reduced fuel usage.[19] This reduction produces an important co-benefit to air quality and health and welfare in local communities. Currently, the California GHG standards have been adopted by 14 states and the District of Columbia, through the CAA Section 177 opt-in provision.[20]

D. *National Program for Fuel Economy and GHG Emission Standards*

Once the waiver was granted to California in 2009, CARB joined NHTSA and EPA in negotiations to align the federal fuel economy and GHG tailpipe emission standards with California's. On May 7, 2010, NHTSA and EPA finalized a joint rule establishing a National Program consisting of new standards for light-duty motor vehicles for Model Years 2012 through 2016.[21] This national program, also known as the Phase 1 standards, was in large part based on the California GHG tailpipe emissions standards.

Almost immediately following the adoption of the Phase 1 GHG-CAFE standards in 2010, work began on developing standards for Model Year 2017 and beyond. A multi-stakeholder

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(sometimes called the Pavely standards after the Congresswoman who introduced the legislation) two years later, in 2004.

[15] The Bush Administration denial was based on its determination that the waiver should only be allowed for state standards addressing regional or local air pollution problems. Since it considered climate change a "global" issue, the Administration found there were no "compelling or extraordinary conditions" specific to California. EPA, "California State Motor Vehicle Pollution Control Standards; Notice of Decision Denying a Waiver of Clean Air Act Preemption for California's 2009 and Subsequent Model Year Greenhouse Gas Emissions," 73 *Federal Register* 12156, 12161, March 6, 2008.

[16] EPA, "California State Motor Vehicle Pollution Control Standards; Notice of Decision Granting a Waiver of Clean Air Act Preemption for California's 2009 and Subsequent Model Year Greenhouse Gas Emission Standards for New Motor Vehicles," 74 *Federal Register* 32744, July 8, 2009.

[17] *Ibid*. at 32748.

[18] *Ibid*. at 32750

[19] *Ibid*.

[20] Those states are Colorado, Connecticut, Delaware, Maine, Maryland, Massachusetts, New Jersey, New York, Oregon, Pennsylvania, Rhode Island, Vermont, and Washington. New Mexico adopted the California standards in 2007 but has not implemented them.

[21] 75 *Federal Register* 25323, May 7, 2010.

agreement resulted in the promulgation of Phase 2 standards in 2012, with support from California, 13 automakers, states and localities, the United Autoworkers Union, auto suppliers, NGOs, and national security experts.[22] The new emission standards for Model Years 2017 through 2025 would cut GHG emissions from vehicles by about 50% by 2025 from their 2010 levels. More stringent fuel economy standards were to be implemented in two phases. For Model Years 2017-2021, the rule required an increase to about 41 mpg on average, while it was anticipated that a later rulemaking would increase fuel efficiency to almost 50 mpg by 2025.[23]

Importantly, CARB agreed that the federal standards "harmonized" with California's and that compliance with the federal standards would be deemed sufficient to show compliance with its program for the 2017-2025 Model Years. On January 9, 2013, EPA confirmed its grant of a preemption waiver to California for the State's Advanced Clean Car (ACC) regulations, which combined "the control of smog and soot causing pollutants and GHG emissions into a single coordinated package" and included revisions to its low emissions vehicle (LEV) and ZEV programs.[24]

While the Phase 2 standards increased fuel economy and tightened GHG tailpipe emissions, it also provided flexibilities for automakers to better enable compliance. Generally, the standards were based on a fleet-wide performance and on the size or "footprint" of the vehicle; thus, larger vehicles such as trucks and SUVs would have a less stringent target, whereas smaller cars had to achieve greater reductions.[25] Moreover, automakers could generate and accumulate credits by over-complying with the standards. These credits could be banked and used to carry forward to apply to a future year if needed, carried backward to cover noncompliance in past years, transferred between a manufacturer's fleet sizes (e.g., from cars to trucks), or sold and transferred to other manufacturers.[26]

Because of the long-term application of the CAFE standards, the Phase 2 rulemaking required EPA to conduct a Mid-Term Evaluation (MTE) no later than April 1, 2018, to determine the appropriateness of the standards for Model Years 2022-2025. As part of the evaluation, EPA, NHTSA, and CARB issued a joint draft Technical Assessment Report (TAR) in July 2016 that reviewed the technologies and marketplace and economic issues to determine the feasibility of

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[22] EPA and NHTSA, "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards; Final Rule," 77 *Federal Register* 62624, October 15, 2012.
[23] *Ibid*. at 62639.
[24] EPA, California State Motor Vehicle Pollution Control Standards; Notice of Decision Granting a Waiver of Clean Air Act Preemption for California's Advanced Clean Car Program and a Within the Scope Confirmation for California's Zero Emission Vehicle Amendments for 2017 and Earlier Model Years, 78 *Federal Register* 2111 (January 9, 2013).
[25] A vehicle's "footprint" technically is "the area defined by the points where the tires contact the ground." *Ibid*. at 62631.
[26] NHTSA, "Fact Sheet: NHTSA and EPA Propose to Extend the National Program to Improve Fuel Economy and Greenhouse Gases for Passenger Cars and Light Trucks," p. 9.

meeting the future standards.[27] In the final months of the Obama Administration, EPA, basing its findings on the TAR, proposed and finalized its MTE determination that the 2012 standards remained "feasible, practical, and appropriate"[28] and should not be strengthened or weakened.

E. *The Trump Proposal to Weaken the Federal Standards and Revoke California's Waiver*

Shortly after President Trump took office in 2017, he announced his Administration was re-examining and reconsidering EPA's Final Determination that the 2012 standards were appropriate.[29] In April 2018, the Administration withdrew the prior MTE Final Determination, and four months later EPA and NHTSA ("the Agencies") issued proposed amendments.[30] The proposed Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021-2026 Passenger Cars and Light Trucks significantly weakens the existing GHG emissions and CAFE rules. The Agencies' "preferred alternative" will keep the existing Model Year 2017-2020 CAFE and GHG standards and then freeze them at the Model Year 2020 levels through Model Year 2026.[31] Thus, the progress in emissions reductions required by the existing standards from Model Year 2021 through 2025 will be stopped dead in its tracks. No additional emissions reductions will be required after the 2020 Model Year.[32] The Administration justifies the changes by claiming that the rollback, compared to the existing standards, will "save over 500 billion dollars in societal costs and reduce highway fatalities by 12,700 lives," yet admits that "U.S. fuel consumption would increase by about half a million barrels per day (2-3 percent of total daily consumption)."[33]

To exacerbate the weakening of the federal emissions standards, EPA proposes to revoke California's waiver of preemption for its package of light-duty vehicle GHG emissions standards and ZEV regulations.[34] This not only takes away California's ability to use its statutory

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[27] EPA, NHTSA, and CARB, "Draft Technical Assessment Report: Midterm Evaluation of Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards for Model Years 2022-2025," EPA-420-D-16-900, July 2016.

[28] EPA, "Proposed Determination on the Appropriateness of the Model Year 2022-2025 Light-Duty Vehicle Greenhouse Gas Emissions Standards under the Midterm Evaluation," 81 *Federal Register* 87928, December 6, 2016; EPA, "Final Determination on the Appropriateness of the Model Year 2022-2025 Light-Duty Vehicle Greenhouse Gas Emissions Standards under the Midterm Evaluation," EPA-420-R-17-001, Jan. 2017.

[29] National Public Radio, August 14, 2017, https://www.npr.org/2017/08/14/543474251/trump-administration-takes-key-step-to-rolling-back-auto-fuel-standards.

[30] EPA, "Mid-Term Evaluation of Greenhouse Gas Emissions Standards for Model Year 2022–2025 Light-Duty Vehicles: Notice; Withdrawal," 83 *Federal Register* 16077, April 13, 2018; EPA, "The Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021-2026 Passenger Cars and Light Trucks," 83 *Federal Register* 42986, August 24, 2018.

[31] EPA's eight proposed regulatory alternatives ranged from freezing the standards at the 2020 levels to making slight per-year increases (0.5-2% for cars and 0.5-3%) through 2026. The "preferred alternative," and the one we will examine herein, proposes a 0% increase in stringency for Model Years 2021 through 2026.

[32] 83 *Federal Register* at 42993.

[33] *Ibid*. at 42986.

[34] *Ibid*. at 43240. For a discussion of the legality of EPA's proposed revocation of California's preemption waiver, see Institute for Policy Integrity, "No Turning Back," Oct. 2018, https://policyintegrity.org/publications/detail/no-turning-back.

authorities to require emissions reductions from the transportation sector, but also eliminates that tool for the Section 177 states and the District of Columbia, which have determined those reductions are necessary to achieve healthy air quality.[35]

III. THE SAFE VEHICLES PROPOSAL'S FAULTY ANALYSIS

In its analysis, NHTSA employs an alternative methodology—different computer modeling, inputs, and basic underlying assumptions—from the proven protocols on which EPA typically relies. Scientists, economists, and transportation experts have analyzed this methodology, revealing its flawed assessments, inaccurate technical and economic assumptions, modeling errors, and incomplete analysis.[36] The flawed methodology severely underestimates the increase in vehicle emissions from the SAFE Vehicles proposal, while it severely overestimates the proposal's purported cost savings and safety improvements. As described below, each departure from the typical modeling and assumptions appears to be for the sole purpose of justifying the weakened standards.

A. *Faulty Assumption #1: Americans Would Drive 1.8 Trillion Miles Less with Weakened Standards*

There are many overlapping false assumptions that corrupt the conclusions of the Administration related to the behavior of consumers and of automakers. Most of the so-called safety and environmental benefits asserted by the SAFE Vehicles proposal are based on the

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[35] *Ibid*. The Agencies state that, "EPA proposes to conclude that States may not adopt California's GHG standards pursuant to section 177 because the text, context, and purpose of section 177 support the conclusion that this provision is limited to providing States the ability, under certain circumstances and with certain conditions, to adopt and enforce standards designed to control criteria pollutants to address NAAQS nonattainment."

[36] Many of the comments submitted to EPA during the regulatory comment period and subsequent articles analyze the flawed assumptions used to justify the SAFE Vehicles proposal. See, e.g., Comment of Antonio Bento, Professor of Public Policy and Economics at the University of Southern California, Oct. 26, 2018, https://www.regulations.gov/document?D=EPA-HQ-OAR-2018-0283-4024; Comment of Wendy B. Jacobs, Esq., Environmental Law & Policy Clinic at Harvard Law School, Oct. 26, 2018, https://www.regulations.gov/document?D=EPA-HQ-OAR-2018-0283-5486; Comments of Environmental Defense Fund on the SAFE Vehicles proposal and Draft EIS and technical appendices, including in Appendix B, a report by EDF consultant, Richard Rykowski, *Review of the Agencies' Technical Analysis Supporting the SAFE Vehicle NPRM*, ("EDF Comments") Oct. 26, 2018, https://www.regulations.gov/document?D=EPA-HQ-OAR-2018-0283-5764 ("EDF Comments on Draft EIS"), https://www.regulations.gov/document?D=EPA-HQ-OAR-2018-0283-5775 (Comment and Appendices on SAFE Vehicles Proposal); Union of Concerned Scientists, Comments and Technical Appendix, Oct. 26, 2018, https://www.regulations.gov/document?D=EPA-HQ-OAR-2018-0283-5840 ("UCS Comments"), Oct. 26, 2018; California Air Resources Board Comments and Technical Appendix ("CARB Comments"), https://ww2.arb.ca.gov/sites/default/files/2018-10/2018-10-26%20FINAL%20CARB%20Detailed%20Comments%20on%20SAFE%20NPRM.pdf. See also, Bento, A.M., K. Gillingham, et al. Dec. 7, 2018. "Flawed analyses of U.S. auto fuel economy standards," *Science*, vol. 362, pp. 1119-1121; "Trump Administration Analysis: Freezing Clean Car Standards Would Cause Hundreds of Fatalities Per Year and Sicken Thousands: Omitted Analysis Contradicts Justification for Freezing Standards," *Public Citizen*, Aug. 27, 2018, https://www.citizen.org/sites/default/files/fatalities-from-rolling-back-clean-cars-standard.pdf; "Clean Cars Rollback: The Absurdity of the Trump Administration's Safety Claims," *Public Citizen* (Aug. 16, 2018), http://bit.ly/2MJvcDX.

assumption that if the standards were rolled back and frozen, Americans would drive 1.8 trillion miles *less* than under the current stronger standards,[37] which would result in fewer highway fatalities and lessen the impact of a weaker fuel economy requirement on emissions compared to the existing standards. To simplify the Administration's thinking, if people get fewer miles to the gallon they'll drive a lot less and, therefore, will reduce their odds of dying in a traffic accident, and their less-driven cars won't spew as many emissions

This is not only dubious on its face, but the methods used to come up with this conclusion have been shown to be contrary to standard economic theory.[38] For example, when a car gets better fuel economy, drivers will sometimes drive more because their fuel costs are less. Experts account for this "rebound" effect when estimating the number of vehicle miles that will be traveled if fuel economy standards are more stringent. Placing its thumb on the modeling scales, however, the SAFE Vehicles proposal *doubled* the magnitude of what experts say is the outer limit of this effect, thus producing a scenario under which many more miles will be driven under the current standards, thereby increasing the projected effects on both traffic fatalities and emissions.[39] Moreover, the Agencies claim that under the current standards the cost of a new car will dramatically rise, so instead of scrapping their old vehicles, people will keep them, resulting in 6 million more cars on the road (all driven the same number of miles), which will increase traffic fatalities and emissions, thus making the SAFE Vehicles proposal look better by comparison.[40]

A closer look at the passenger safety benefits of the SAFE Vehicles proposal reveals that "97-99 percent of NHTSA's projected fatality reductions are simply due to flawed assumptions about how people will change their driving habits under the proposed rollback—driving new cars less based on an exaggerated rebound effect and driving used cars less as well due to a new and deeply flawed scrappage model."[41]

B. *Faulty Assumption #2: Automakers' Over-compliance*

Another questionable assumption used to lower the emissions levels projected to result from the weakened standards was that auto manufacturers would voluntarily over-comply with the Model Year 2020 standards under the SAFE Vehicles proposal, thereby reducing GHG and criteria pollutants emissions.[42] This assumption is not based on historical performance nor

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[37] 83 *Federal Register* at 43,351.

[38] See, e.g., EDF Comments; UCS Comments. Moreover, using dubious assumptions about how Americans will scrap or keep their old cars, the SAFE Vehicles proposal also claims that weakening the standards will actually shrink the projected number of vehicles on the road by 6 million compared to the existing standards. Bento, A.M., K. Gillingham, et al.. "Flawed analyses of U.S. auto fuel economy standards," *Science,* Dec. 7, 2018.

[39] "[T]he agencies have arbitrarily doubled the effect of rebound, ignoring past precedent as well as the body of academic literature, often mischaracterizing the work cited in support of their erroneous value for rebound," UCS Comments, 6.

[40] Bento, A.M., "Flawed analyses of U.S. auto fuel economy standards," *Science,* Dec. 7, 2018.

[41] EDF Comments, 2.

[42] 83 *Federal Register* at 43283-85. EDF Comments, Appendix B, 29-32.

does it have any reasonable basis in fact.[43] Moreover, the SAFE Vehicles proposal completely ignores the ability of automakers to trade and sell compliance credits under the weakened standards, which could nullify some of the claimed overall decrease in emissions.[44] In fact, EPA's just-released 2018 Automotive Trends Report found that the industry retained a "large bank" of credits that can be used in future model years.[45]

C. *Faulty Assumption #3: Vast Overestimation of the Costs to Manufacturers of Meeting the Existing, Stronger Standards*

Again demonstrating the inconsistency in its comparisons between the two rules, the SAFE Vehicles proposal vastly overestimates the costs to manufacturers of meeting the existing standards, despite its claims that manufacturers will over-comply with the weaker standards.[46] The assumptions underlying this outcome do not take in to account automakers' ability to trade/sell compliance credits, which would lower costs for both compliers and those in noncompliance. Moreover, and inexplicably, this rationale completely omits future lower-cost technology options, assuming instead that more expensive technologies would be used.[47] As confirmed in EPA's 2018 Automotive Trends Report, manufacturers are quickly adopting some advanced technologies, such as cylinder deactivation, more rapidly than anticipated.[48]

D. *Faulty Assumption #4: Underestimation of Effects of Increased Fuel Consumption*

The SAFE proposal analysis admits that additional gasoline will be consumed by the less efficient vehicles under weakened standards. It downplays, however, the domestic environmental effects from the upstream emissions associated with production and transportation of the extra fuel, claiming that 90% of the increased gasoline consumption will come from imported crude sources and that half would be refined outside of the United States.[49] This assumption is inconsistent with the fact that almost all fuel in the United States is produced and refined domestically, and is even directly contradicted in another part of the

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[43] CARB Comments, 163-164; EDF Comments, Appendix B, 31, "[O]verall, manufacturers have historically just complied with the standards or even paid CAFE fines due to under-compliance, offering no assurance that such over-compliance would indeed occur under the proposed standards."

[44] EDF Comments, 3, EDF Comments, Appendix B, 5; USC Comments, 4.

[45] EPA, 2018 Automotive Trends Report: Greenhouse Gas Emissions, Fuel Economy, and Technology since 1975, Executive Report, pp.ES-11-ES-12, https://www.epa.gov/automotive-trends/highlights-automotive-trends-report. "2018 Trends Report."

[46] Bento, *Science*; UCS Comments, 4; EDF Comments, Appendix B, 9.

[47] *Ibid*; EDF Comments, Appendix B, 9, "[R]eviewers found severe problems with NHTSA's estimates of the costs and effectiveness of individual technologies. NHTSA also unreasonably restricted the use of several highly effective technologies from use. These deficiencies doubled NHTSA's projected compliance costs compared to its own analysis performed only two years ago for the Technical Analysis Review (TAR), which was still based on an inefficient application of technology."

[48] EPA, 2018 Trends Report, ES-7-ES-8.

[49] 83 *Federal Register* at 43335.

proposed rule that tries to claim that improvements in fuel economy are not necessary for national security because of the huge increases in domestic production.[50]

IV. THE SAFE VEHICLES PROPOSAL WILL LEAD TO SIGNIFICANT INCREASES IN GHG EMISSIONS

The Trump Administration's own analysis projects GHG emissions increasing under the weakened standards compared to the existing ones.[51] NHTSA's 2018 Draft Environmental Impact Statement (Draft EIS) supporting the proposed rule concludes that the "preferred alternative" will increase annual GHG emissions by 95 million metric tons in 2040 compared to the existing standards.[52] The Agencies estimate an increase in climate damages from added GHG emissions (domestic, not global) of between $2.7 and $4.7 billion.[53]

Modeling that corrects for the false assumptions and technical deficiencies highlighted above projects that GHG emissions will increase by nearly double the amounts estimated in the Draft EIS for each model year—including an *annual* emissions increase of 189 million metric tons by 2040 compared to the existing standards—with increased *annual* emissions of 200 million tons of CO_2 by 2050.[54] By 2040, if the standards are frozen at 2020 levels, an additional 2.2 billion metric tons of GHG emissions will have been added to the atmosphere that could have been avoided had the existing standards remained.[55]

The harmful impacts from increased GHG emissions, both globally and domestically, on the changing climate are well documented[56] and have been the subject of many analyses and criticisms of the proposed rule. Less well known and analyzed, however, are the many significant harmful impacts promulgation of the SAFE Vehicles proposal will have due to substantial increases in *non-GHG emissions*, including of smog-forming pollution, fine particles,

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[50] 83 *Federal Register* at 42993. "The U.S. is now the world's largest oil producer and expected to become a net petroleum exporter in the next decade."

[51] 83 *Federal Register* at 43066-43067. "Increased refining and consumption of petroleum-based fuel will increase emissions of carbon dioxide and other greenhouse gases that theoretically contribute to climate change, and some of the resulting (albeit uncertain) increase in economic damages from future changes in the global climate will be borne throughout the U.S. economy (line 13)." NHTSA and EPA, Preliminary Regulatory Impact Analysis: The Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Year 2021 – 2026 Passenger Cars and Light Trucks, July 2018, https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/ld_cafe_my2021-26_pria_0.pdf.

[52] Draft Environmental Impact Statement for The Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Year 2021–2026 Passenger Cars and Light Trucks, July 2018, 5-28, Appendix D, Tables D-9 and D-10. See EDF Comments on DEIS, 6.

[53] 83 *Federal Register* at 43062-065.

[54] EDF used the Volpe model employed by NHTSA in its analysis, making alterations that "correct errors in the Volpe model and conform the analysis to NHTSA's historical approach and the underlying factual record." EDF Comments on DEIS, 3-4. EDF Comments, Appendix B, 9, 94-101 "We show that correcting only some of these biased assumptions changes the proposal from producing a net societal benefit to producing sizeable net societal costs. We also show that instead of saving thousands of lives by getting less safe vehicles off of the road, the proposal is likely to increase thousands of deaths from increased ambient levels of fine particulate matter (PM)."

[55] UCS Comments, Technical Appendix, 64.

[56] See, e.g., USGCRP, 2018: Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II: Report-in-Brief ("National Climate Assessment"), https://nca2018.globalchange.gov.

sulfur oxides, and air toxics. This paper shines a light on those impacts so that communities and decision makers will fully understand what is at stake if the Administration weakens the existing emission standards.

V. THE SAFE VEHICLES PROPOSAL WILL LEAD TO SIGNIFICANT INCREASES IN NON-GHG EMISSIONS

The Trump Administration admits that the SAFE proposal weakening the standards will increase non-GHG emissions of air pollution.[57] The proposal's Preliminary Regulatory Impact Statement concludes that the "added fuel production and use will increase emissions of more localized air pollutants (or their chemical precursors)," resulting in an increase in "the U.S. population's exposure to harmful levels of these pollutants" and "adverse effects on health."[58] The increase is derived primarily from increased fuel consumption under the proposed weakening of the standards. Higher fuel demand means more emissions from "petroleum extraction, refining and distribution of motor vehicle fuels."[59]

In addition, NHTSA estimates that for "NO_X (in 2050), $PM_{2.5}$, SO_2, and VOCs (in 2035 and 2050), emissions would generally increase across action alternatives (compared to the [current standards]), with the largest increases occurring under [the preferred alternative]."[60]

Even in the preamble to the proposed rule, the Agencies admit that "NO_x, VOC, SO_2, and $PM_{2.5}$ increase" in 2035, although they claim that "[f]or all criteria pollutants, the overall impact of the proposed program would be small compared to total U.S. inventories across all sectors."[61]

Referring to this impact as "small" is misleading and deceptive, however. First, even if one assumes the overall emissions increases are "small" on a national level, the localized impacts for communities at risk may be quite large. Second, when the flawed assumptions and other errors in the NHTSA modeling are corrected, projections show dramatic increases in criteria pollutant and toxic emissions from what would be expected if existing standards were left in place.[62] For example, while NHTSA estimates SO_x emissions would increase by 8,838 metric tons per year by 2035 if the standards were rolled back and frozen, a corrected analysis projects an increase of 30,238 metric tons per year.[63] Smog-forming emissions (VOCs and NOx) would increase by over 100,000 metric tons by 2035 compared to NHTSA's estimate of around

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[57] 83 *Federal Register* at 43066-43067.
[58] NHTSA and EPA, Preliminary Regulatory Impact Analysis: The Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Year 2021 – 2026 Passenger Cars and Light Trucks, July 2018, at 1091-1092, https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/ld_cafe_my2021-26_pria_0.pdf.
[59] Comments of the National Association of Clean Air Agencies ("NACAA comments"), Oct. 26, 2018, 2-3, https://www.regulations.gov/document?D=EPA-HQ-OAR-2018-0283-4185.
[60] Draft EIS, S-7.
[61] 83 *Federal Register* at 43330.
[62] EDF Comments on DEIS, 7.
[63] EDF Comments, Appendix A, 50.

13,000.[64] Particulate matter ($PM_{2.5}$) emissions would increase by 3,693 metric tons in 2035 compared to the NHTSA figure of 324 tons.[65]

The national impacts of the SAFE Vehicles proposal obviously will spill over to the states, which will have to deal with the local effects of these increases. For example, according to an analysis by CARB, the weakened standards will create "an additional 1.24 tons per day of NO_x emissions in the South Coast air basin, 90 percent of which is from upstream fuel activity increases."[66] This would require removing from the road "either an additional 1.3 million clean conventional vehicles or 1 million zero emission vehicles" to meet the region's air quality commitments.[67]

The proposal will also have a significant impact on hazardous air pollution in communities around the country. While NHTSA projects hazardous air pollutants will decrease under its proposal, correcting the flawed assumptions shows that emissions from at least two cancer-causing pollutants will actually increase. Revised analysis projects benzene emissions increasing by 134 metric tons in 2030 under the weakened standards and up to 268 tons in 2050, while formaldehyde emissions increase by 44 tons in 2030 and up to 80 tons per year by 2050.[68]

These numbers are significant, but what will these increases in non-GHG emissions mean for public health and welfare, states' compliance with air quality standards, and industry?

VI. THE SAFE VEHICLES PROPOSAL WILL LEAD TO SIGNIFICANT ADVERSE EFFECTS FROM INCREASED NON-GHG EMISSIONS

Clearly, non-GHG emissions will increase if the current federal standards are rolled back and frozen at 2020 levels and California's waiver is revoked. The full effects of those increases have not been widely publicized (i.e., the "untold story"), yet are far ranging. Increased non-GHG emissions under the SAFE Vehicles proposal will seriously affect public health and welfare, will interfere with the states' ability to comply with air quality standards, and will affect industries' plans for construction or expansion in many areas of the country.

A. *Significant Increase in Mortality and Morbidity: National Impacts*

Revised modeling correcting flawed assumptions and other key errors in NHTSA's analysis reveals a terribly disturbing picture of the health impacts of the SAFE Vehicles proposal.

Air quality experts project that the cumulative effects (by 2050) of the SAFE Vehicles proposal could cause the premature deaths of up to 32,000 people, and serious illnesses and other

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[64] *Ibid*. at 51.
[65] *Ibid*. at 49.
[66] CARB Comments, 288.
[67] *Ibid*.
[68] EDF Comments, Appendix A, 49-50.

harmful effects to tens of millions of others, just from the anticipated increases in $PM_{2.5}$.[69] Health-related incidences include, among others, up to: 40,089 respiratory emergency room visits; 126,057 cases of acute bronchitis; 10.4 million work loss days; and 2.3 million cases of asthma exacerbation.[70] The monetary cost of these premature deaths and health-related impacts from the weakened standards could be anywhere from $4.4 to 9.8 billion in 2030.[71]

The Trump Administration's recent National Climate Assessment confirmed how harmful increases in $PM_{2.5}$ emissions can be, stating, "$PM_{2.5}$ accounts for most of the health impacts due to air pollution in the United States, and *small changes in average concentrations have large implications for public health* (emphasis added)."[72]

Moreover, increased GHG emissions will exacerbate local air pollution problems. The National Climate Assessment confirms the compounding health impacts from hotter temperatures and drought caused by increased GHG emissions, concluding, "Unless counteracting efforts to improve air quality are implemented, climate change will worsen existing air pollution levels. This worsened air pollution would increase the incidence of adverse respiratory and cardiovascular health effects, including premature death. Increased air pollution would also have other environmental consequences, including reduced visibility and damage to agricultural crops and forests."[73]

Even the Trump Administration acknowledges the harmful effects of its proposal from non-GHG emissions. The Administration asserts in the SAFE Vehicles preamble that increases in emissions will have "negligible environmental impacts on air quality,"[74] yet estimates the "societal costs" of those impacts will be up to $1.2 billion.[75] Only in NHTSA's Draft EIS is it explained what those "costs" are in terms of people dying and getting sick. NHTSA estimates that the proposal would cause as many as 299 premature deaths per year by 2050 and "would result in increased adverse health impacts (mortality, acute bronchitis, respiratory emergency room visits, and work-loss days [from 2025 through 2050]) nationwide compared to the [existing standards] as a result of increases in emissions of $PM_{2.5}$, [diesel particulate matter],

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[69] EDF Comments, Appendix A, 55-56. See Table 1, below, which sets forth cumulative health effects from 2017 to 2050 from $PM_{2.5}$ under the SAFE Vehicles proposal.

[70] *Ibid*.

[71] *Ibid*. at 55-56.

[72] National Climate Assessment, https://nca2018.globalchange.gov/chapter/13/. See Public Citizen, Aug. 27, 2018, p.2.

[73] *Ibid*. The increases under the weakened standards from NO_x and VOCs are particularly troubling. "Unless offset by additional emissions reductions of ozone precursor emissions, there is high confidence that climate change will increase ozone levels over most of the United States, particularly over already polluted areas, thereby worsening the detrimental health and environmental effects due to ozone."

[74] 83 *Federal Register* at 42996. Later in the proposed rule the Agencies admit that they could not "accurately project" the emission changes under the new rule projections because there was not time to perform the air quality modeling for $PM_{2.5}$, ozone precursors and toxics emissions on future ambient concentrations that would be required for final promulgation.

[75] 83 *Federal Register* at 43062–067; NHTSA Draft Environmental Impact Statement, July 18, 2018. See Public Citizen, "Trump Administration Analysis: Freezing Clean Car Standards Would Cause Hundreds of Fatalities Per Year and Sicken Thousands: Omitted Analysis Contradicts Justification for Freezing Standards" Aug. 27, 2018, 2.

and SO_x."[76] What is terribly ironic is that the Trump Administration justifies the proposed rollback of the standards with erroneous claims that the proposal will save lives from traffic fatalities because of fewer vehicle miles traveled, yet downplays the huge and harmful mortality and morbidity impacts from increased non-GHG emissions.

B. *Significant Increase in Mortality and Morbidity: State and Local Impacts*

The mortality and morbidity figures from $PM_{2.5}$ alone are alarming when calculated on a national level. These health impacts of increased $PM_{2.5}$ emissions can be drilled down to the state level. In the Appendix we have quantified for each of the 48 contiguous states and Washington, D.C., the estimated incidences of the health and welfare effects that will occur if the SAFE Vehicles proposal is promulgated. The effects we examined include premature mortality; respiratory emergency room visits; acute bronchitis; lower respiratory symptoms; upper respiratory symptoms; minor restricted activity days; work loss days; asthma exacerbation; cardiovascular hospital admissions; respiratory hospital admissions; and non-fatal heart attacks.

What is clear from our analysis is that every state in the country will experience adverse health and welfare effects from the SAFE Vehicles proposal. Some states' impacts are especially alarming.

In Texas, for example, we estimate that over 3,700 people could die prematurely and over 7 million could face "restricted activity days" by 2050 as a result of the SAFE Vehicles rule. Pennsylvania and New York are expected to have similar impacts; Pennsylvania could see almost 2,000 premature deaths and about 3.7 million restricted activity days, while New York is estimated to have almost 1,900 premature deaths and over 3.5 million restricted activity days. We estimate that Ohio could face up to 1,430 premature deaths and more than 2.7 million restricted work activities, while Florida could see over 1,000 premature deaths and about 2 million restricted work days. No region of the country is immune.

Moreover, these health-related problems will be worse for those least able to afford them. The increase in upstream emissions from the SAFE Vehicles proposal will adversely affect pockets of the country that already are at risk because they are located near industrial or heavily trafficked areas. Connecticut's air pollution control agency points out that "[t]he insidious direct and irreparable effects of the SAFE rule victimize our most at risk citizens, as is conceded by EPA's own modeling. This proposal decreases jobs, increases both GHG's and criteria pollutants, and further threatens those who do not have the means to escape the worst effects of climate change."[77]

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[76] Draft EIS, S-9. The Draft EIS estimates that by 2050, the weakened standards would cause annually between 134 and 299 premature deaths; 199 extra cases of acute bronchitis; 16,819 cases of work-loss days; and 62 extra emergency room visits. Draft EIS, at 4-47.

[77] Comment submitted by Robert J. Klee, Commissioner, Connecticut Department of Energy and Environmental Protection (DEEP), October 26, 2018, https://www.regulations.gov/document?D=EPA-HQ-OAR-2018-0283-4202

The Minnesota air pollution control agency reiterates in its comments opposing the SAFE Vehicles proposal: "States also rely on these [existing] standards to achieve criteria pollutant and toxic air pollution reductions. Vehicle emissions account for almost a quarter of Minnesota's overall emissions, are one of the primary sources of risk from outdoor air pollution, and disproportionately impact communities of color and lower income. The existing standards are therefore critical for states to attain and maintain the National Ambient Air Quality Standards to protect the health of their communities."[78]

Those most harmed by the increases in criteria pollutants and toxics under the SAFE Vehicles proposal will be those most at risk because of the locations of their communities closest to the source of pollution.[79]

C. *Significant Impact on States' Compliance with the Clean Air Act*

Increases in non-GHG emissions from the SAFE Vehicles proposal will jeopardize the ability of states and localities to comply with the NAAQS under the CAA. States with air quality violating the health-based standards (i.e., nonattainment areas) may not be able to comply as planned. States currently meeting the standards (i.e., attainment areas), but very close to exceeding them, may be pushed into nonattainment. As described below, both scenarios result in serious impacts on states and localities.

Areas Violating the NAAQS: Under the CAA, a state with an area exceeding the health-based NAAQS must develop a SIP that demonstrates to EPA's satisfaction all of the strategies the state will employ to achieve compliance by the statutory deadlines. Vehicle emissions typically account for a third of our nation's smog problems, although in some areas they may be the predominant source of emissions. It is therefore imperative that state strategies take full advantage of the significant and cost-effective emissions reductions available from the transportation sector. In fact, as the states' air quality association has indicated, the SIPS submitted by states and localities are counting on the reductions from the existing vehicle emissions rule to attain or maintain compliance with the NAAQS.[80] Many of these states have taken advantage of their right under CAA Section 177 to adopt California's emissions standards in their plans to achieve compliance. Revoking the California waiver and the states' right to opt in will dramatically affect those plans. The SAFE Vehicles proposal creates at least three problematic scenarios for these states and localities.

First, if the SAFE Vehicles proposal is promulgated, states will be responsible for finding other regulatory options to compensate for the emissions reductions they were expecting from the existing rule. These other options invariably will be costlier and less cost-effective than ones in

[78] Comment submitted by John Linc Stine, Jan K. Malcolm & Charles A. Zelle, Commissioner, Minnesota Pollution Control Agency (MPCA) et al., October 26, 2018, https://www.regulations.gov/document?D=EPA-HQ-OAR-2018-0283-5459.
[79] CARB Comments, 294-301.
[80] National Association of Clean Air Agencies (NACAA) Comments, 2. See CARB comments, 288.

states' current SIPs, for they will have to come from existing sources that have already put on controls or smaller sources that did not require regulatory requirements in the past.

Air pollution control is a zero-sum venture—meaning if control measures states had planned for one sector of their economy, such as transportation, do not achieve the emissions reductions they are counting on, they will have to take reductions from another sector.[81] In some areas of the country, however, "there simply are no other sources; reaching or maintaining clean air goals relies entirely on adequately addressing mobile source emissions."[82] Metropolitan D.C., for example, with little industry to pull from, relies almost exclusively on vehicle emission reductions to plan for compliance with the ozone standard. As the Metropolitan D.C. air agency commented in its opposition to the SAFE Vehicles proposal, "While significant progress has been made in the Washington region to reduce emissions, addressing sources of NO_x, including those from on-road vehicles, is critical to continuing to deliver cleaner air for the residents of the region. We are concerned that any relaxation of the 2012 Greenhouse Gas and CAFE Final Rule will make it increasingly difficult for the region to realize the reductions in NO_x emissions needed to comply with the 2015 Ozone NAAQS."[83]

Second, if states are unable to make up for the increased emissions resulting from the SAFE Vehicles proposal, their SIPs could be deemed out of compliance with the CAA, triggering mandatory economic sanctions. These sanctions include 1) the withholding of tens of millions of dollars in federal highway funds for state transportation projects, as well as 2) stringent emissions offset requirements on new businesses that want to locate in an area or existing facilities that plan to expand their operations (i.e., they must reduce their emissions by two tons for every one ton they propose to emit). These offsets can be very expensive and difficult to obtain, acting in effect as a construction moratorium in those nonattainment areas.

Third, many nonattainment areas are close to attaining one or more of the NAAQS, but the SAFE Vehicles proposal could jeopardize compliance. For example, there are over a dozen ozone nonattainment areas throughout the country that are within 5 parts per billion (ppb) of attaining the 8-hour 70-ppb limit (i.e., their "ozone design values" are between 70-75 ppb). For these areas, compliance with the standard could be delayed if the SAFE Vehicles proposal is adopted. According to EPA's most recent air quality data, these areas include, among others, Baltimore, MD, Washington, D.C., St. Louis, MO, Cleveland, Columbus and Cincinnati, OH, Detroit, MI, Milwaukee, WI, Louisville, KY, San Antonio, TX, Dona Ana County, NM, San Francisco and San Luis Obispo, CA, Southern Wasatch Front, UT and Yuma, AZ.[84]

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[81] NACAA Comment, 2-3, 7. "A cleaner, low-emissions transportation sector is essential to achieve state and local climate goals and meet and sustain federal air quality standards. These states and localities will not accomplish this without increasingly more protective GHG vehicle emission standards and the ZEV program."

[82] NACAA Comments, 7.

[83] Comment submitted by Hans Riemer, Chair, Metropolitan Washington Air Quality Committee (MWAQC), Mary Lehman, Chair, Climate Energy and Environment Policy Committee (CEEPC), and Charles Allen, Chair, National Capital Region Transportation Planning Board (TPB), Metropolitan Washington Air Quality Committee (MWAQC), https://www.regulations.gov/document?D=EPA-HQ-OAR-2018-0283-3326.

[84] EPA Air Trends, https://www.epa.gov/air-trends/air-quality-design-values#map.

This is not just theoretical speculation. The U.S. Conference of Mayors and National League of Cities, in a letter signed by over 60 state and local leaders, warn of the impacts to the air quality in their communities if the SAFE Vehicles proposal is promulgated. "[V]ehicle emissions impact air quality and a community's ability to meet required ozone levels. Falling outside of required ozone levels can have negative impacts on cities, potentially disqualifying them from federal funding opportunities for highway and transit infrastructure. Robust vehicle emission standards are key to ensuring cities are able to meet ozone requirements."[85]

Areas Attaining the NAAQS: There are a number of areas throughout the country that are meeting the NAAQS now, but just barely. With increases in air pollutants projected from the SAFE Vehicles proposal, those areas on the cusp could be pushed into nonattainment, which will trigger a host of SIP requirements. These areas will be required to develop SIPs—many for the first time—and subject their sources to stringent air pollution measures, including state-of-the-art controls, offset requirements, and many others. For example, according to state/local monitoring data provided to EPA, there are over 200 counties in 40 states where ozone levels are within 5 parts per billion of the 8-hour 70-ppb NAAQS.[86] The increases in emissions from rolling back the current standards and revoking the California waiver and ZEV requirements could have a huge impact on many of those areas on the border between attainment and nonattainment.

Government officials understand the dramatic impact on their states and localities if the increases in emissions from the SAFE Vehicles proposal push their area into nonattainment including:

- North Carolina: "[R]elaxing the light-duty vehicle standards would increase ozone precursor emissions that would place our urban areas at risk for exceeding the current ozone NAAQS."[87]
- Kansas: "The Kansas City region has struggled to meet the National Ambient Air Quality Standards (NAAQS) for ozone pollution for many years. While the region is currently designated as attainment for the 2015 standard, monitored values indicate we are barely attaining this standard and must continue to work to reduce ozone precursor emissions from all sources to remain in compliance. National regulations such as fuel economy standards help the Kansas City region remain in compliance with the ozone NAAQS and reduce regulatory burden on all types of sources in the region as a result. With the anticipation of additional vehicles on the road and increased fuel consumption as outlined in this proposed

[85] Comment submitted by Tom Cochran, CEO and Executive Director, The U.S. Conference of Mayors and Clarence E. Anthony, CEO and Executive Director, National League of Cities, https://www.regulations.gov/document?D=EPA-HQ-OAR-2018-0283-4154.

[86] EPA, Air Quality Statistics by County, 2017, https://www.epa.gov/sites/production/files/2018-07/ctyfactbook2017.xlsx.

[87] Comment submitted by Sheila C. Holman, Assistant Secretary for the Environment, North Carolina Department of Environmental Quality (NCDEQ), https://www.regulations.gov/document?D=EPA-HQ-OAR-2018-0283-4209.

rule, it would be more difficult for the Kansas City region to continue to meet the ozone NAAQS in the future."[88]

- Tucson, Arizona: "Freezing emission reductions for six years could put this region in jeopardy of being designated as non-attainment of the ozone standard and impact the health of many of our most vulnerable residents. The designation of Pima County as non-attainment for the ozone standard will likely necessitate the implementation of additional air quality-related regulations that will affect local businesses and transportation planning."[89]

D. *Significant Impact on Businesses*

Rolling back and freezing the standards will create regulatory and economic uncertainty and upheaval in the states and localities. As explained above, the projected emissions reductions that the states have relied upon from the existing standards will be eliminated and new reductions will need to be obtained. Accordingly, state officials have two options: 1) either return to businesses and manufacturers for additional emissions reductions; or 2) require emissions reductions from smaller "mom-and-pop" facilities, such as bakeries, dry cleaners and auto body shops, that can ill afford to retrofit their operations. Both of these options are unfair, create equity issues, and undermine those businesses that have acted in good faith.

Industry likes certainty for planning purposes and economic stability. Some companies will be loath to locate in areas if there is uncertainty as to what controls they will have to employ to meet their permitting requirements. If an area is close to the attainment level for the NAAQS, industry might be hesitant to move in to that area if projected emissions under the SAFE Vehicles proposal will trigger sanctions or onerous pollution control requirements.

Governors hopeful that a growing economy will draw new industry into their states will be stymied if they cannot predict the impact that the SAFE Vehicles proposal will have on their ability to meet air quality standards. The uncertainty and potential for stricter future pollution controls could deter new industry from building in these areas and existing businesses from expanding.

VII. WAIVER REVOCATION PROFOUNDLY INCREASES THE HARM FROM THE SAFE VEHICLES PROPOSAL

States rely on the reductions from the existing emissions standards to comply with state and federal ambient air quality standards. These reductions will be lost if the SAFE Vehicles proposal is promulgated. To add insult to injury, the SAFE Vehicles proposal seeks to revoke the California waiver and the state's GHG and ZEV programs on which many states and

[88] Comment submitted by Legislator Scott Burnett, Missouri Co-Chair, Air Quality Forum and Commissioner Angela Markley, Kansas Co-Chair, Air Quality Forum, Mid-America Regional Council (MARC), https://www.regulations.gov/document?D=EPA-HQ-OAR-2018-0283-4123.

[89] Comment submitted by Ursula Nelson, Director, Pima County Department of Environmental Quality (PDEQ), https://www.regulations.gov/document?D=EPA-HQ-OAR-2018-0283-6204.

localities rely. States are now facing a double whammy to their projected compliance goals—significantly weaker federal standards and revocation of the California waiver.[90] It would be extremely disturbing if the Trump Administration proceeds with weakening the existing federal motor vehicle emissions standards, thereby depriving states and localities of the anticipated additional and important air pollution emissions reductions necessary to provide a healthful environment. It would be unconscionable, however, if, on top of these roll-backs, the Administration also revokes California's waiver, depriving that state—as well as the additional Section 177 states—of the insurance policy needed to offset the weakening of the existing standards.

In the tables that follow in the Appendix, we quantify the health and welfare impacts of the Trump Administration's proposal to weaken the existing federal GHG motor vehicle emissions standards. Table 1 displays the nationwide cumulative non-GHG emissions effects—including estimated numbers of premature deaths—of rolling back the federal standards and revoking California's waiver. We break down these data by state in the subsequent tables.

VIII. CONCLUSION

In conclusion, we have determined that the Safe Vehicles rule is so severely flawed that it must be rescinded. We have shown that it will cause millions of people to die prematurely or get sick from the increases in non-GHG emissions. The proposed rule will also wreck havoc on the ability of states to comply with the national health-based air quality standards and constrain businesses that wish to expand their operations. It has been reported that the Administration will make some modest adjustments to its proposal. These changes are almost certainly to be minor and will not change our conclusions regarding the impacts of non-GHG emissions increases on society.

[90] CARB Comments, 336.

APPENDIX

TABLE 1

CUMULATIVE EFFECTS OF THE SAFE VEHICLES PROPOSAL ON $PM_{2.5}$-RELATED HEALTH IMPACTS FROM 2017-2050

NATIONWIDE IMPACTS (Number of Incidences)*

Premature Mortality	14,501-32,362
Respiratory Emergency Room Visits	40,089
Acute Bronchitis	126,057
Lower Respiratory Symptoms	1,623,910
Upper Respiratory Symptoms	2,299,464
Minor Restricted Activity Days	61,424,459
Work Loss Days	10,395,427
Asthma Exacerbation	2,358,166
Cardiovascular Hospital Admissions	30,418
Respiratory Hospital Admissions	24,887
Non-Fatal Heart Attacks	94,492

*Comments of Environmental Defense Fund on National Highway Traffic Safety Administration's and Environmental Protection Agency's Proposed Rule: The Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021–2026 Passenger Cars and Light Trucks, 83 Fed. Reg. 42,986 (Aug. 24, 2018); Docket No. EPA-HQ-OAR-2018-0283; https://www.regulations.gov/document?D=EPA-HQ-OAR-2018-0283-5775.

TABLES OF
STATE-BY-STATE IMPACTS

THE HEALTH CONSEQUENCES OF PRESIDENT TRUMP'S SAFE VEHICLES PROPOSAL TO ROLL BACK FEDERAL GHG VEHICLE EMISSIONS STANDARDS*

* The methodology used to calculate the state-by-state impacts includes the following steps: 1) Use the Environmental Defense Fund analysis (Technical Analysis Review for EDF, Rykowski Report, p. 86) to calculate the *national* cumulative PM-related health impacts from 2017 to 2050 (see Table 1, above). EDF based its calculations on EPA's Technical Support Document, "Estimating the Benefit per Ton of Reducing $PM_{2.5}$ Precursors From 17 Sectors," EPA, OAQPS, 2/2018; 2) Use EPA's Co-Benefits Risk Assessment (COBRA) Screening Model to identify the state-by-state percentages that are applied to the national health impacts. (https://www.epa.gov/statelocalenergy/co-benefits-risk-assessment-cobra-health-impacts-screening-and-mapping-tool).

THE CUMULATIVE HEALTH IMPACTS OF ADOPTING THE TRUMP ADMINISTRATION'S SAFE VEHICLES PROPOSAL (Number of Incidences)

Alabama

Premature Mortality	139-311
Respiratory Emergency Room Visits	385
Acute Bronchitis	1,210
Lower Respiratory Symptoms	15,590
Upper Respiratory Symptoms	22,075
Minor Restricted Activity Days	589,675
Work Loss Days	99,796
Asthma Exacerbation	22,638
Cardiovascular Hospital Admissions	292
Respiratory Hospital Admissions	239
Non-Fatal Heart Attacks	907

Arizona

Premature Mortality	189-421
Respiratory Emergency Room Visits	521
Acute Bronchitis	1,639
Lower Respiratory Symptoms	21,111
Upper Respiratory Symptoms	29,893
Minor Restricted Activity Days	798,518
Work Loss Days	135,141
Asthma Exacerbation	30,656
Cardiovascular Hospital Admissions	395
Respiratory Hospital Admissions	324
Non-Fatal Heart Attacks	1,228

THE CUMULATIVE HEALTH IMPACTS OF ADOPTING THE TRUMP ADMINISTRATION'S SAFE VEHICLES PROPOSAL (Number of Incidences)

Arkansas

Premature Mortality	129-288
Respiratory Emergency Room Visits	357
Acute Bronchitis	1,122
Lower Respiratory Symptoms	14,453
Upper Respiratory Symptoms	20,465
Minor Restricted Activity Days	546,678
Work Loss Days	93,559
Asthma Exacerbation	20,988
Cardiovascular Hospital Admissions	271
Respiratory Hospital Admissions	221
Non-Fatal Heart Attacks	841

California

Premature Mortality	3,096-6,909
Respiratory Emergency Room Visits	8,559
Acute Bronchitis	26,913
Lower Respiratory Symptoms	133,205
Upper Respiratory Symptoms	490,936
Minor Restricted Activity Days	13,114,122
Work Loss Days	2,219,424
Asthma Exacerbation	503,468
Cardiovascular Hospital Admissions	649
Respiratory Hospital Admissions	5,313
Non-Fatal Heart Attacks	20,174

THE CUMULATIVE HEALTH IMPACTS OF ADOPTING THE TRUMP ADMINISTRATION'S SAFE VEHICLES PROPOSAL (Number of Incidences)

Colorado

Premature Mortality	136-304
Respiratory Emergency Room Visits	377
Acute Bronchitis	1,185
Lower Respiratory Symptoms	15,265
Upper Respiratory Symptoms	21,615
Minor Restricted Activity Days	577,390
Work Loss Days	97,717
Asthma Exacerbation	22,167
Cardiovascular Hospital Admissions	286
Respiratory Hospital Admissions	234
Non-Fatal Heart Attacks	888

Connecticut

Premature Mortality	138-307
Respiratory Emergency Room Visits	381
Acute Bronchitis	1,198
Lower Respiratory Symptoms	15,427
Upper Respiratory Symptoms	21,845
Minor Restricted Activity Days	583,532
Work Loss Days	98,757
Asthma Exacerbation	22,403
Cardiovascular Hospital Admissions	289
Respiratory Hospital Admissions	236
Non-Fatal Heart Attacks	898

THE HEALTH IMPACTS OF ADOPTING THE TRUMP ADMINISTRATION'S SAFE VEHICLES PROPOSAL (Number of Incidences)

Delaware

Premature Mortality	46-104
Respiratory Emergency Room Visits	128
Acute Bronchitis	403
Lower Respiratory Symptoms	5,197
Upper Respiratory Symptoms	7,358
Minor Restricted Activity Days	196,558
Work Loss Days	33,265
Asthma Exacerbation	7,546
Cardiovascular Hospital Admissions	97
Respiratory Hospital Admissions	80
Non-Fatal Heart Attacks	302

District of Columbia

Premature Mortality	20-45
Respiratory Emergency Room Visits	56
Acute Bronchitis	176
Lower Respiratory Symptoms	2,273
Upper Respiratory Symptoms	3,219
Minor Restricted Activity Days	85,994
Work Loss Days	14,554
Asthma Exacerbation	3,301
Cardiovascular Hospital Admissions	43
Respiratory Hospital Admissions	35
Non-Fatal Heart Attacks	14

THE HEALTH IMPACTS OF ADOPTING THE TRUMP ADMINISTRATION'S SAFE VEHICLES PROPOSAL (Number of Incidences)

Florida

Premature Mortality	460-1,026
Respiratory Emergency Room Visits	1,271
Acute Bronchitis	3,996
Lower Respiratory Symptoms	51,478
Upper Respiratory Symptoms	72,893
Minor Restricted Activity Days	1,947,155
Work Loss Days	329,535
Asthma Exacerbation	74,754
Cardiovascular Hospital Admissions	943
Respiratory Hospital Admissions	789
Non-Fatal Heart Attacks	2,995

Georgia

Premature Mortality	255-570
Respiratory Emergency Room Visits	706
Acute Bronchitis	2,219
Lower Respiratory Symptoms	28,581
Upper Respiratory Symptoms	40,471
Minor Restricted Activity Days	1,081,070
Work Loss Days	182,960
Asthma Exacerbation	41,504
Cardiovascular Hospital Admissions	535
Respiratory Hospital Admissions	438
Non-Fatal Heart Attacks	1,663

THE HEALTH IMPACTS OF ADOPTING THE TRUMP ADMINISTRATION'S SAFE VEHICLES PROPOSAL (Number of Incidences)

Idaho

Premature Mortality	30-68
Respiratory Emergency Room Visits	84
Acute Bronchitis	265
Lower Respiratory Symptoms	3,410
Upper Respiratory Symptoms	4,829
Minor Restricted Activity Days	128,991
Work Loss Days	21,830
Asthma Exacerbation	4,952
Cardiovascular Hospital Admissions	64
Respiratory Hospital Admissions	52
Non-Fatal Heart Attacks	198

Illinois

Premature Mortality	735-1,641
Respiratory Emergency Room Visits	2,033
Acute Bronchitis	6,391
Lower Respiratory Symptoms	82,332
Upper Respiratory Symptoms	116,583
Minor Restricted Activity Days	3,114,220
Work Loss Days	527,048
Asthma Exacerbation	119,559
Cardiovascular Hospital Admissions	1,542
Respiratory Hospital Admissions	1,262
Non-Fatal Heart Attacks	4,791

THE HEALTH IMPACTS OF ADOPTING THE TRUMP ADMINISTRATION'S SAFE VEHICLES PROPOSAL (Number of Incidences)

Indiana

Premature Mortality	273-608
Respiratory Emergency Room Visits	754
Acute Bronchitis	2,370
Lower Respiratory Symptoms	30,530
Upper Respiratory Symptoms	43,230
Minor Restricted Activity Days	1,154,780
Work Loss Days	195,434
Asthma Exacerbation	44,334
Cardiovascular Hospital Admissions	572
Respiratory Hospital Admissions	468
Non-Fatal Heart Attacks	1,776

Iowa

Premature Mortality	99-220
Respiratory Emergency Room Visits	273
Acute Bronchitis	857
Lower Respiratory Symptoms	11,043
Upper Respiratory Symptoms	15,636
Minor Restricted Activity Days	417,686
Work Loss Days	70,669
Asthma Exacerbation	16,036
Cardiovascular Hospital Admissions	207
Respiratory Hospital Admissions	169
Non-Fatal Heart Attacks	643

THE HEALTH IMPACTS OF ADOPTING THE TRUMP ADMINISTRATION'S SAFE VEHICLES PROPOSAL (Number of Incidences)

Kansas

Premature Mortality	116-259
Respiratory Emergency Room Visits	321
Acute Bronchitis	1,008
Lower Respiratory Symptoms	12,991
Upper Respiratory Symptoms	18,396
Minor Restricted Activity Days	491,396
Work Loss Days	83,163
Asthma Exacerbation	18,865
Cardiovascular Hospital Admissions	243
Respiratory Hospital Admissions	124
Non-Fatal Heart Attacks	756

Kentucky

Premature Mortality	168-375
Respiratory Emergency Room Visits	465
Acute Bronchitis	1,462
Lower Respiratory Symptoms	18,837
Upper Respiratory Symptoms	26,674
Minor Restricted Activity Days	712,524
Work Loss Days	120,587
Asthma Exacerbation	27,355
Cardiovascular Hospital Admissions	353
Respiratory Hospital Admissions	289
Non-Fatal Heart Attacks	1,096

THE HEALTH IMPACTS OF ADOPTING THE TRUMP ADMINISTRATION'S SAFE VEHICLES PROPOSAL (Number of Incidences)

Louisiana

Premature Mortality	302-673
Respiratory Emergency Room Visits	834
Acute Bronchitis	2,622
Lower Respiratory Symptoms	33,777
Upper Respiratory Symptoms	47,829
Minor Restricted Activity Days	1,277,629
Work Loss Days	216,225
Asthma Exacerbation	49,050
Cardiovascular Hospital Admissions	633
Respiratory Hospital Admissions	518
Non-Fatal Heart Attacks	1,965

Maine

Premature Mortality	45-103
Respiratory Emergency Room Visits	124
Acute Bronchitis	391
Lower Respiratory Symptoms	5,034
Upper Respiratory Symptoms	7,128
Minor Restricted Activity Days	190,416
Work Loss Days	32,226
Asthma Exacerbation	7,310
Cardiovascular Hospital Admissions	94
Respiratory Hospital Admissions	77
Non-Fatal Heart Attacks	293

THE HEALTH IMPACTS OF ADOPTING THE TRUMP ADMINISTRATION'S SAFE VEHICLES PROPOSAL (Number of Incidences)

Maryland

Premature Mortality	268-599
Respiratory Emergency Room Visits	742
Acute Bronchitis	2,332
Lower Respiratory Symptoms	30,042
Upper Respiratory Symptoms	42,540
Minor Restricted Activity Days	1,136,352
Work Loss Days	192,315
Asthma Exacerbation	43,626
Cardiovascular Hospital Admissions	563
Respiratory Hospital Admissions	460
Non-Fatal Heart Attacks	1,748

Massachusetts

Premature Mortality	189-421
Respiratory Emergency Room Visits	521
Acute Bronchitis	1,639
Lower Respiratory Symptoms	21,111
Upper Respiratory Symptoms	29,893
Minor Restricted Activity Days	798,518
Work Loss Days	135,141
Asthma Exacerbation	30,656
Cardiovascular Hospital Admissions	395
Respiratory Hospital Admissions	324
Non-Fatal Heart Attacks	1,228

THE HEALTH IMPACTS OF ADOPTING THE TRUMP ADMINISTRATION'S SAFE VEHICLES PROPOSAL (Number of Incidences)

Michigan

Premature Mortality	406-906
Respiratory Emergency Room Visits	1,122
Acute Bronchitis	3,530
Lower Respiratory Symptoms	45,469
Upper Respiratory Symptoms	64,385
Minor Restricted Activity Days	1,719,885
Work Loss Days	291,072
Asthma Exacerbation	66,029
Cardiovascular Hospital Admissions	852
Respiratory Hospital Admissions	697
Non-Fatal Heart Attacks	2,646

Minnesota

Premature Mortality	157-350
Respiratory Emergency Room Visits	433
Acute Bronchitis	1,361
Lower Respiratory Symptoms	17,538
Upper Respiratory Symptoms	24,834
Minor Restricted Activity Days	663,384
Work Loss Days	112,271
Asthma Exacerbation	25,468
Cardiovascular Hospital Admissions	329
Respiratory Hospital Admissions	269
Non-Fatal Heart Attacks	1,021

THE HEALTH IMPACTS OF ADOPTING THE TRUMP ADMINISTRATION'S SAFE VEHICLES PROPOSAL (Number of Incidences)

Mississippi

Premature Mortality	93-207
Respiratory Emergency Room Visits	257
Acute Bronchitis	807
Lower Respiratory Symptoms	10,393
Upper Respiratory Symptoms	14,717
Minor Restricted Activity Days	393,117
Work Loss Days	66,531
Asthma Exacerbation	15,092
Cardiovascular Hospital Admissions	195
Respiratory Hospital Admissions	159
Non-Fatal Heart Attacks	605

Missouri

Premature Mortality	291-650
Respiratory Emergency Room Visits	806
Acute Bronchitis	2,534
Lower Respiratory Symptoms	32,641
Upper Respiratory Symptoms	46,219
Minor Restricted Activity Days	1,234,632
Work Loss Days	208,948
Asthma Exacerbation	47,399
Cardiovascular Hospital Admissions	611
Respiratory Hospital Admissions	500
Non-Fatal Heart Attacks	1,899

THE HEALTH IMPACTS OF ADOPTING THE TRUMP ADMINISTRATION'S SAFE VEHICLES PROPOSAL (Number of Incidences)

Montana

Premature Mortality	33-74
Respiratory Emergency Room Visits	92
Acute Bronchitis	290
Lower Respiratory Symptoms	3,735
Upper Respiratory Symptoms	5,289
Minor Restricted Activity Days	141,276
Work Loss Days	23,909
Asthma Exacerbation	5,424
Cardiovascular Hospital Admissions	70
Respiratory Hospital Admissions	57
Non-Fatal Heart Attacks	217

Nebraska

Premature Mortality	51-113
Respiratory Emergency Room Visits	140
Acute Bronchitis	441
Lower Respiratory Symptoms	5,684
Upper Respiratory Symptoms	8,048
Minor Restricted Activity Days	214,986
Work Loss Days	36,384
Asthma Exacerbation	8,254
Cardiovascular Hospital Admissions	106
Respiratory Hospital Admissions	87
Non-Fatal Heart Attacks	331

THE HEALTH IMPACTS OF ADOPTING THE TRUMP ADMINISTRATION'S SAFE VEHICLES PROPOSAL (Number of Incidences)

Nevada

Premature Mortality	100-223
Respiratory Emergency Room Visits	277
Acute Bronchitis	870
Lower Respiratory Symptoms	11,205
Upper Respiratory Symptoms	15,866
Minor Restricted Activity Days	423,829
Work Loss Days	71,728
Asthma Exacerbation	16,271
Cardiovascular Hospital Admissions	210
Respiratory Hospital Admissions	172
Non-Fatal Heart Attacks	652

New Hampshire

Premature Mortality	41-91
Respiratory Emergency Room Visits	112
Acute Bronchitis	353
Lower Respiratory Symptoms	4,547
Upper Respiratory Symptoms	6,438
Minor Restricted Activity Days	171,988
Work Loss Days	29,107
Asthma Exacerbation	6,603
Cardiovascular Hospital Admissions	85
Respiratory Hospital Admissions	70
Non-Fatal Heart Attacks	265

THE HEALTH IMPACTS OF ADOPTING THE TRUMP ADMINISTRATION'S SAFE VEHICLES PROPOSAL (Number of Incidences)

New Jersey

Premature Mortality	481-1,074
Respiratory Emergency Room Visits	1,331
Acute Bronchitis	4,185
Lower Respiratory Symptoms	53,914
Upper Respiratory Symptoms	76,342
Minor Restricted Activity Days	2,039,292
Work Loss Days	345,128
Asthma Exacerbation	78,291
Cardiovascular Hospital Admissions	1,010
Respiratory Hospital Admissions	826
Non-Fatal Heart Attacks	3,137

New Mexico

Premature Mortality	55-123
Respiratory Emergency Room Visits	152
Acute Bronchitis	479
Lower Respiratory Symptoms	6,171
Upper Respiratory Symptoms	8,738
Minor Restricted Activity Days	233,413
Work Loss Days	39,503
Asthma Exacerbation	8,961
Cardiovascular Hospital Admissions	116
Respiratory Hospital Admissions	95
Non-Fatal Heart Attacks	359

THE HEALTH IMPACTS OF ADOPTING THE TRUMP ADMINISTRATION'S SAFE VEHICLES PROPOSAL (Number of Incidences)

New York

Premature Mortality	840-1,874
Respiratory Emergency Room Visits	2,321
Acute Bronchitis	7,299
Lower Respiratory Symptoms	94,024
Upper Respiratory Symptoms	133,139
Minor Restricted Activity Days	3,556,476
Work Loss Days	601,895
Asthma Exacerbation	136,538
Cardiovascular Hospital Admissions	1,761
Respiratory Hospital Admissions	1,441
Non-Fatal Heart Attacks	5,471

North Carolina

Premature Mortality	290-647
Respiratory Emergency Room Visits	802
Acute Bronchitis	2,521
Lower Respiratory Symptoms	32,478
Upper Respiratory Symptoms	45,989
Minor Restricted Activity Days	1,228,489
Work Loss Days	207,909
Asthma Exacerbation	47,163
Cardiovascular Hospital Admissions	608
Respiratory Hospital Admissions	498
Non-Fatal Heart Attacks	1,890

THE HEALTH IMPACTS OF ADOPTING THE TRUMP ADMINISTRATION'S SAFE VEHICLES PROPOSAL (Number of Incidences)

North Dakota

Premature Mortality	20-45
Respiratory Emergency Room Visits	56
Acute Bronchitis	176
Lower Respiratory Symptoms	2,273
Upper Respiratory Symptoms	3,219
Minor Restricted Activity Days	85,994
Work Loss Days	14,554
Asthma Exacerbation	3,301
Cardiovascular Hospital Admissions	43
Respiratory Hospital Admissions	35
Non-Fatal Heart Attacks	132

Ohio

Premature Mortality	641-1,430
Respiratory Emergency Room Visits	1,772
Acute Bronchitis	5,572
Lower Respiratory Symptoms	71,777
Upper Respiratory Symptoms	101,636
Minor Restricted Activity Days	2,714,961
Work Loss Days	459,478
Asthma Exacerbation	104,231
Cardiovascular Hospital Admissions	1,344
Respiratory Hospital Admissions	1,100
Non-Fatal Heart Attacks	4,177

THE HEALTH IMPACTS OF ADOPTING THE TRUMP ADMINISTRATION'S SAFE VEHICLES PROPOSAL (Number of Incidences)

Oklahoma

Premature Mortality	199-443
Respiratory Emergency Room Visits	549
Acute Bronchitis	1,727
Lower Respiratory Symptoms	22,248
Upper Respiratory Symptoms	31,503
Minor Restricted Activity Days	841,515
Work Loss Days	142,417
Asthma Exacerbation	32,307
Cardiovascular Hospital Admissions	417
Respiratory Hospital Admissions	341
Non-Fatal Heart Attacks	1,295

Oregon

Premature Mortality	55-123
Respiratory Emergency Room Visits	1,520
Acute Bronchitis	479
Lower Respiratory Symptoms	6,171
Upper Respiratory Symptoms	8,738
Minor Restricted Activity Days	233,413
Work Loss Days	39,503
Asthma Exacerbation	8,961
Cardiovascular Hospital Admissions	116
Respiratory Hospital Admissions	95
Non-Fatal Heart Attacks	359

THE HEALTH IMPACTS OF ADOPTING THE TRUMP ADMINISTRATION'S SAFE VEHICLES PROPOSAL (Number of Incidences)

Pennsylvania

Premature Mortality	874-1,951
Respiratory Emergency Room Visits	2,417
Acute Bronchitis	7,601
Lower Respiratory Symptoms	97,922
Upper Respiratory Symptoms	138,658
Minor Restricted Activity Days	3,703,895
Work Loss Days	626,844
Asthma Exacerbation	142,197
Cardiovascular Hospital Admissions	1,834
Respiratory Hospital Admissions	1,501
Non-Fatal Heart Attacks	5,698

Rhode Island

Premature Mortality	36-81
Respiratory Emergency Room Visits	100
Acute Bronchitis	315
Lower Respiratory Symptoms	4,060
Upper Respiratory Symptoms	5,749
Minor Restricted Activity Days	153,561
Work Loss Days	25,989
Asthma Exacerbation	5,895
Cardiovascular Hospital Admissions	76
Respiratory Hospital Admissions	62
Non-Fatal Heart Attacks	236

THE HEALTH IMPACTS OF ADOPTING THE TRUMP ADMINISTRATION'S SAFE VEHICLES PROPOSAL (Number of Incidences)

South Carolina

Premature Mortality	132-294
Respiratory Emergency Room Visits	365
Acute Bronchitis	1,147
Lower Respiratory Symptoms	14,778
Upper Respiratory Symptoms	20,925
Minor Restricted Activity Days	558,963
Work Loss Days	12,698
Asthma Exacerbation	21,459
Cardiovascular Hospital Admissions	277
Respiratory Hospital Admissions	226
Non-Fatal Heart Attacks	860

South Dakota

Premature Mortality	20-45
Respiratory Emergency Room Visits	56
Acute Bronchitis	176
Lower Respiratory Symptoms	2,273
Upper Respiratory Symptoms	3,219
Minor Restricted Activity Days	85,994
Work Loss Days	14,554
Asthma Exacerbation	3,301
Cardiovascular Hospital Admissions	43
Respiratory Hospital Admissions	35
Non-Fatal Heart Attacks	132

THE HEALTH IMPACTS OF ADOPTING THE TRUMP ADMINISTRATION'S SAFE VEHICLES PROPOSAL (Number of Incidences)

Tennessee

Premature Mortality	284-634
Respiratory Emergency Room Visits	786
Acute Bronchitis	2,471
Lower Respiratory Symptoms	30,854
Upper Respiratory Symptoms	45,069
Minor Restricted Activity Days	1,203,919
Work Loss Days	203,750
Asthma Exacerbation	46,220
Cardiovascular Hospital Admissions	596
Respiratory Hospital Admissions	488
Non-Fatal Heart Attacks	1,852

Texas

Premature Mortality	1,663-3,712
Respiratory Emergency Room Visits	4,598
Acute Bronchitis	14,459
Lower Respiratory Symptoms	186,262
Upper Respiratory Symptoms	263,749
Minor Restricted Activity Days	7,045,385
Work Loss Days	1,192,355
Asthma Exacerbation	270,482
Cardiovascular Hospital Admissions	3,489
Respiratory Hospital Admissions	2,855
Non-Fatal Heart Attacks	10,838

THE HEALTH IMPACTS OF ADOPTING THE TRUMP ADMINISTRATION'S SAFE VEHICLES PROPOSAL (Number of Incidences)

Utah

Premature Mortality	55-123
Respiratory Emergency Room Visits	152
Acute Bronchitis	479
Lower Respiratory Symptoms	6,171
Upper Respiratory Symptoms	8,738
Minor Restricted Activity Days	233,413
Work Loss Days	39,503
Asthma Exacerbation	8,961
Cardiovascular Hospital Admissions	116
Respiratory Hospital Admissions	95
Non-Fatal Heart Attacks	359

Vermont

Premature Mortality	20-45
Respiratory Emergency Room Visits	56
Acute Bronchitis	176
Lower Respiratory Symptoms	2,273
Upper Respiratory Symptoms	3,219
Minor Restricted Activity Days	85,994
Work Loss Days	14,554
Asthma Exacerbation	3,301
Cardiovascular Hospital Admissions	43
Respiratory Hospital Admissions	35
Non-Fatal Heart Attacks	132

THE HEALTH IMPACTS OF ADOPTING THE TRUMP ADMINISTRATION'S SAFE VEHICLES PROPOSAL (Number of Incidences)

Virginia

Premature Mortality	280-625
Respiratory Emergency Room Visits	774
Acute Bronchitis	2,433
Lower Respiratory Symptoms	31,341
Upper Respiratory Symptoms	44,380
Minor Restricted Activity Days	1,185,492
Work Loss Days	200,632
Asthma Exacerbation	45,513
Cardiovascular Hospital Admissions	587
Respiratory Hospital Admissions	480
Non-Fatal Heart Attacks	1,824

Washington

Premature Mortality	200-447
Respiratory Emergency Room Visits	553
Acute Bronchitis	1,740
Lower Respiratory Symptoms	22,410
Upper Respiratory Symptoms	31,739
Minor Restricted Activity Days	847,658
Work Loss Days	143,457
Asthma Exacerbation	32,543
Cardiovascular Hospital Admissions	420
Respiratory Hospital Admissions	343
Non-Fatal Heart Attacks	1,304

THE HEALTH IMPACTS OF ADOPTING THE TRUMP ADMINISTRATION'S SAFE VEHICLES PROPOSAL (Number of Incidences)

West Virginia

Premature Mortality	141-314
Respiratory Emergency Room Visits	389
Acute Bronchitis	1,223
Lower Respiratory Symptoms	15,752
Upper Respiratory Symptoms	22,305
Minor Restricted Activity Days	595,817
Work Loss Days	100,836
Asthma Exacerbation	22,874
Cardiovascular Hospital Admissions	295
Respiratory Hospital Admissions	241
Non-Fatal Heart Attacks	917

Wisconsin

Premature Mortality	190-424
Respiratory Emergency Room Visits	525
Acute Bronchitis	1,651
Lower Respiratory Symptoms	21,273
Upper Respiratory Symptoms	30,123
Minor Restricted Activity Days	804,660
Work Loss Days	136,180
Asthma Exacerbation	30,892
Cardiovascular Hospital Admissions	398
Respiratory Hospital Admissions	326
Non-Fatal Heart Attacks	1,238

THE HEALTH IMPACTS OF ADOPTING THE TRUMP ADMINISTRATION'S SAFE VEHICLES PROPOSAL (Number of Incidences)

Wyoming

Premature Mortality	16-36
Respiratory Emergency Room Visits	44
Acute Bronchitis	139
Lower Respiratory Symptoms	1,786
Upper Respiratory Symptoms	2,529
Minor Restricted Activity Days	67,567
Work Loss Days	11,435
Asthma Exacerbation	2,594
Cardiovascular Hospital Admissions	33
Respiratory Hospital Admissions	27
Non-Fatal Heart Attacks	104

For Immediate Release

Bill Becker
301-806-6111
bbecker744@comcast.net

TRUMP PROPOSAL WEAKENING VEHICLE GHG EMISSIONS STANDARDS CAUSES HORRIFIC IMPACTS ON PUBLIC HEALTH, STATES COMPLIANCE WITH THE CLEAN AIR ACT AND INDUSTRY OPERATIONS, ACCORDING TO NEW REPORT

Tens of thousands of people could die prematurely and millions of others develop serious health problems if the Trump Administration's proposal to roll back the Obama clean-car standards is adopted, according to a report released today. Most attention has been focused on the impact of the proposal's weakening of greenhouse gas and related fuel economy requirements. This new report, *The Devastating Impacts of the Trump Proposal to Roll Back Greenhouse Gas Vehicle Emissions Standards* reveals that the most devastating, but little discussed, aspect of the Trump plan is that it would *also* have huge collateral effects from increases in emissions from pollutants other than greenhouse gases, such as smog-forming pollutants, fine particles, and cancer-causing air toxins. According to the report's co-author, Bill Becker, former Executive Director of the National Association of Clean Air Agencies, "these harmful effects will have a direct impact on people's health and will be felt in every state in the country."

The devastating impacts of the Trump proposal extend well beyond the horrific health and welfare effects. The proposal, which freezes vehicle emissions standards and rescinds California's and other states' authorities, severely jeopardizes states' compliance with the Clean Air Act. In particular, Becker says, "states clean air strategies will be busted, triggering severe economic sanctions, including the withholding of millions of dollars in federal highway funds." The expected increases in emissions could also delay compliance with health-based standards and place up to 200 "clean air" counties in jeopardy of violating the health-based standards.

The Trump proposal, says Becker, could also impose severe consequences on businesses. "Companies may be loathe to locate in communities facing regulatory uncertainty, be constrained from expanding their operations, and face additional requirements to make up for the proposal's expected increases in emissions."

In light of these impacts, the authors have recommended that the Trump Administration rescind its proposal.

XXX

Message

From: grundler.christopher@epa.gov [grundler.christopher@epa.gov]
Sent: 4/23/2019 10:34:35 PM
To: Steve.Cliff@arb.ca.gov
Subject: Fwd: EMA??

FYI

Christopher Grundler, Director
Office of Transportation and Air Quality
U.S. Environmental Protection Agency
202.564.1682 (Washington DC)
734.214.4207 (Ann Arbor MI)
734.645.5221 (mobile)
www.epa.gov/otaq

Begin forwarded message:

> **From:** "Charmley, William" <charmley.william@epa.gov>
> **Date:** April 23, 2019 at 6:31:45 PM EDT
> **To:** "Grundler, Christopher" <grundler.christopher@epa.gov>
> **Subject: Re: EMA??**
>
> I went only for the first hour, and I took about 30 to 40 minutes explaining why we need ARB at these technical meetings, and that is our plan going forward.
>
> I don't have anyone from EMA (Tim French or Matt Spears) or any of the members
>
> **Deliberative Process / Ex. 5**
>
> There were a few more thoughts on this I have and I can catch up with you tomorrow.
>
> I don't know how the actual meeting went with EMA, I had never planned on going at all, and I only went for the first hour because of this issue regarding CARB participation
>
> Thanks
> Bill
>
> Sent from my iPhone
>
> On Apr 23, 2019, at 6:15 PM, Grundler, Christopher <grundler.christopher@epa.gov> wrote:
>
> ---
> Christopher Grundler, Director
> Office of Transportation and Air Quality
> U.S. Environmental Protection Agency
> 202.564.1682 (Washington DC)

734.214.4207 (Ann Arbor MI)
Personal Matters / Ex. 6 (mobile)
www.epa.gov/otaq

Appointment

From: Bunker, Byron [bunker.byron@epa.gov]
Sent: 4/29/2019 2:15:52 PM
To: Bunker, Byron [bunker.byron@epa.gov]; Brooks, Phillip [Brooks.Phillip@epa.gov]; Belser, Evan [Belser.Evan@epa.gov]; Grundler, Christopher [grundler.christopher@epa.gov]; Cook, Leila [cook.leila@epa.gov]; Wehrly, Linc [wehrly.linc@epa.gov]; Hebert, Annette@ARB [annette.hebert@arb.ca.gov]; Cathey, Tawanna [Cathey.Tawanna@epa.gov]

Subject: Sidley Austin Self-Disclosure
Location: C174 in Ann Arbor, Video to DC DCRoomARS1142/DC-ARIEL-RIOS-OECA-OCE, CARB via conference line

Start: 4/29/2019 3:00:00 PM
End: 4/29/2019 4:00:00 PM
Show Time As: Tentative

Conference Line: Conference Line/Code / Ex. 6
Conference ID: Conference Line/Code / Ex. 6

Appointment

From: Bunker, Byron [bunker.byron@epa.gov]
Sent: 4/29/2019 2:15:52 PM
To: Bunker, Byron [bunker.byron@epa.gov]; Brooks, Phillip [Brooks.Phillip@epa.gov]; Belser, Evan [Belser.Evan@epa.gov]; Grundler, Christopher [grundler.christopher@epa.gov]; Cook, Leila [cook.leila@epa.gov]; Wehrly, Linc [wehrly.linc@epa.gov]; Hebert, Annette@ARB [annette.hebert@arb.ca.gov]; Cathey, Tawanna [Cathey.Tawanna@epa.gov]

Subject: Sidley Austin - Justin Savage
Location: C174 in Ann Arbor, Video to DC DCRoomARS1142/DC-ARIEL-RIOS-OECA-OCE, CARB via conference line

Start: 4/29/2019 3:00:00 PM
End: 4/29/2019 4:00:00 PM
Show Time As: Tentative

Conference Line: Conference Line/Code / Ex. 6
Conference ID: Conference Line/Code / Ex. 6

Appointment

From: Wang, Lee@ARB [Lee.Wang@arb.ca.gov]
Sent: 4/19/2019 4:16:19 PM
To: Wang, Lee@ARB [Lee.Wang@arb.ca.gov]; Baumgard Kirby J [BaumgardKirbyJ@JohnDeere.com]; Beth Hinchee [Hinchee_Beth_A@cat.com]; Brian Bolton [Brian.Bolton@hmmusa.com]; ellis [ellis@hino.com]; Aaron Neuman [Aaron.Neuman@Daimler.com]; Cullen, Angela [cullen.angela@epa.gov]; Anne-Marie Williams [Anne-Marie.Williams@Navistar.com]; Arvind Thiruvengadam [Arvind.Thiruvengadam@mail.wvu.edu]; Benjamin C. Shade [benjamin.shade@avl.com]; Brent Keppy [Brent.Keppy@us.bosch.com]; Carl Beck [carl.beck@volvo.com]; Charles Benoit Chaumette [Charles-benoit.Chaumette@Daimler.com]; Chris Lemansky [Chris.Lemanski@Daimler.com]; cshimoda@caltrux.org; Chris Wright [Chris.Wright@PACCAR.com]; Costi Nedelcu [costi.nedelcu@paccar.com]; Craig Kazmierczak [Craig.Kazmierczak@Daimler.com]; Daniel Moote [daniel.moote@daimler.com]; Daniel Young [daniel.young@continental-corporation.com]; Dave Polivka [Dave.Polivka@Navistar.com]; David Kayes [David.Kayes@Daimler.com]; David Piech [david.piech@cnhind.com]; Dr. Ameya Joshi [JoshiA@corning.com]; Dr. Tue Johannessen [TJ@amminex.com]; Eric Persson [eric.persson@avl.com]; Francisco Posada [francisco@theicct.org]; Frank Seymour [Francis.Seymour_Jr@daimler.com]; Geisick Bryan T [GeisickBryanT@JohnDeere.com]; Geoff Johnson [geoff.johnson2@canada.ca]; George Lin [Lin_George@cat.com]; Mitchell, George [Mitchell.George@epa.gov]; Greg Siuchta [Gregory.Siuchta@Navistar.com]; Hammoud, Rime (EC [rime.hammoud@canada.ca]; Heejung Jung [heejung@engr.ucr.edu]; Heltzel Robert [robert.heltzel@volvo.com]; Jack MacDonnell [jmacdonnell@enermotion.com]; Jackie Yeager [jackie.m.yeager@cummins.com]; James Cigler [James.Cigler@Navistar.com]; James Konstant [Jim.Konstant@Navistar.com]; Jason Pless [Jason.Pless@jmusa.com]; Jeff Zsoldos [jeffrey.zsoldos@volvo.com]; Joanna Bellamy [joanna.bellamy@canada.ca]; Joh Hart [John.Hart@stoneridge.com]; Josephine Davidson [Josephine.davidson@canada.ca]; Julie Deschatelets [Julie.deschatelets@canada.ca]; Kim Hradecky [kimberly.hradecky@canada.ca]; Martin Romzek [Martin.Romzek@eberspaecher.com]; Matt Spears [spears.matthew@epa.gov]; Matthew R. Smith [Matt.Smith@Navistar.com]; Rajani Modiyani [rajani.modiyani@cummins.com]; Robin Willats [robin.willats@faurecia.com]; Sam George [GeorgeS@corning.com]; Shirish Shimpi [shirish.a.shimpi@cummins.com]; Steve Musselman [Steven.Musselman@Daimler.com]; Thomas Lawson [Thomas@cngvc.org]; Timothy A. French [tfrench@emamail.org]; Tom Durbin [durbin@cert.ucr.edu]; Victor Miranda [victor.miranda@navistar.com]; Xavier Faucon [FauconXavier@JohnDeere.com]; Chris Sharp [chris.sharp@swri.org]; Gurpreet Singh [Gurpreet.Singh@ee.doe.gov]; Ken Howden [Ken.Howden@ee.doe.gov]; Robert Wagner [wagnerrm@ornl.gov]; jkubsh@meca.org; Mike Geller [mgeller@Meca.org]; rbrezny@meca.org; Timothy French [tfrench@clpchicago.com]; Jeff Marley [jeff.marley@volvo.com]; 'He Yuesheng' [yuesheng.he@volvo.com]; Berry Steve [steve.berry@volvo.com]; dan.kieffer@paccar.com; Don Keski-Hynnila [donald.keski-hynnila@daimler.com]; Don Stanton [donald.w.stanton@cummins.com]; 'Lisa A Farrell' [lisa.a.farrell@cummins.com]; Russ Zukouski [russ.zukouski@navistar.com]; Laroo, Chris [laroo.chris@epa.gov]; Matthew Spears [mspears@emamail.org]; Zhang, Houshun [Zhang.Houshun@epa.gov]; Nelson, Brian [nelson.brian@epa.gov]; Sanchez, James [sanchez.james@epa.gov]; Yanca, Catherine [yanca.catherine@epa.gov]; aoshinuga@aqmd.gov; Joseph Lopat [jlopat@aqmd.gov]; Thornton, Matthew [Matthew.Thornton@nrel.gov]; Duran, Adam [Adam.Duran@nrel.gov]; Adam Kotrba [AKotrba@Tenneco.com]; Kevin Hallstrom [kevin.hallstrom@basf.com]; Dave Cetola [david.cetola@jmusa.com]; Mark Monohon – [MMonohon@ngksparkplugs.com]; Magana, Pilar@Energy [Pilar.Magana@energy.ca.gov]; Wiens, Jerry@Energy [Jerry.Wiens@energy.ca.gov]; Wiens, Jerry [jwiens@surewest.net]; Magnusson Mathias [mathias.magnusson.2@volvo.com]; Tasik Karl [karl.tasik@volvo.com]; David M Youngren [dave.youngren@basf.com]; jason.martin@daimler.com; Miller Marc [marc.miller@volvo.com]; Anderson Rickey [rickey.anderson@volvo.com]; igor.gruden@daimler.com; jason.barton@daimler.com; jeffrey.murawa@daimler.com; inderpal.singh@daimler.com; Janak, Robb [Robb.Janak@jakebrake.com]; Brian C Mormino [brian.c.mormino@cummins.com]; Landon Sproull [Landon.Sproull@PACCAR.com]; Clark Taylor [taylor.clark@volvo.com]; Mclaughlin Samuel [samuel.mclaughlin@volvo.com]; jeff.foor@fcagroup.com; Razaznejad Behrooz [behrooz.razaznejad@volvo.com]; David B. Brown [david.b.brown@gm.com]; Andersson Lennart (la [lennart.la.andersson@volvo.com]; Gibble John [john.gibble@volvo.com]; Istenes Raymond [raymond.istenes@volvo.com]; Zhang, Chen [Chen.Zhang@nrel.gov]; Miller, Eric [Eric.Miller@nrel.gov]; Kelly, Kenneth [Kenneth.Kelly@nrel.gov]; Mike Gerty [Mike.Gerty@PACCAR.com]; Gui Xinqun [GuiXinqun@JohnDeere.com]; Carlhammar Lars [Lars.Carlhammar@volvo.com]; Matt Stefanick [Stefanick_Matt@cat.com]; toma.codreanu@daimler.com; Lowry, Jeff@ARB [jeffrey.lowry@arb.ca.gov]; alessandro.cozzolini@daimler.com; Hawelti, Daniel@ARB [daniel.hawelti@arb.ca.gov]; Lemieux, Stephan@ARB [stephan.lemieux@arb.ca.gov]; Heroy-Rogalski, Kim@ARB [kim.heroy-rogalski@arb.ca.gov]; Robertson, Bill@ARB [bill.robertson@arb.ca.gov]; Carter, Michael@ARB [michael.carter@arb.ca.gov]; Kitowski, Jack@ARB

[jack.kitowski@arb.ca.gov]; Adnani, Paul@ARB [Paul.Adnani@arb.ca.gov]; Bartolome, Christian@ARB [Christian.Bartolome@arb.ca.gov]; Santos, Alex@ARB [Alex.Santos@arb.ca.gov]; O'Connor, Susan@ARB [susan.o'connor@arb.ca.gov]; Haste, Ron@ARB [Ron.Haste@arb.ca.gov]; Richards, Nadia@ARB [Nadia.Richards@arb.ca.gov]; Lee, Abraham@ARB [abraham.lee@arb.ca.gov]; O'Cain, John@ARB [John.O'Cain@arb.ca.gov]; Tan, Yi@ARB [Yi.Tan@arb.ca.gov]; Herner, Jorn@ARB [jorn.herner@arb.ca.gov]; Yoon, Seungju@ARB [seungju.yoon@arb.ca.gov]; Montes, Thomas@ARB [thomas.montes@arb.ca.gov]; Pazokifard, Babak@ARB [Babak.Pazokifard@arb.ca.gov]; Pryor, Kimberly@ARB [Kim.Pryor@arb.ca.gov]; Lourenco, Jackie@ARB [Jackie.Lourenco@arb.ca.gov]; Regenfuss, Mike@ARB [michael.regenfuss@arb.ca.gov]; Chang, Hung-Li@ARB [hungli.chang@arb.ca.gov]; Jaw, Kathy@ARB [Kathy.Jaw@arb.ca.gov]; Lemieux, Sharon@ARB [sharon.lemieux@arb.ca.gov]; ARB MSCD Meetings And Events [600.mscdcal.ARB@arb.ca.gov]

CC: Wong, Jeffrey@ARB [jwong@arb.ca.gov]; Mahmood, Adil@ARB [Adil.Mahmood@arb.ca.gov]; Ho, Jerry@ARB [Jerry.Ho@arb.ca.gov]; Macias, Keith@ARB [keith.macias@arb.ca.gov]; Vincent Ngo [Vincent.Ngo@arb.ca.gov]; Charmley, William [charmley.william@epa.gov]; timdenoyer@gmail.com; Kenny Vieth [kwvieth@actresearch.net]; Matthew Psota [matthew.psota@cummins.com]; Tim Denoyer [tdenoyer@actresearch.net]; Baltrucki, Justin [Justin.Baltrucki@jakebrake.com]; Weaver Ron [ron.weaver@volvo.com]; Jeff Marsee [Jeff.Marsee@isza.com]; ken.degroot@fcagroup.com; Kevin Fan [KFan@Tenneco.com]; Steve Rubenstein [SRubenstein@Tenneco.com]; Kathleen Horchler [Horchler_Kathleen@cat.com]; frank.krich@fcagroup.com; David W Lake [david.w.lake@gm.com]; dawn.fenton@volvo.com; Hebert, Annette@ARB [annette.hebert@arb.ca.gov]; Grundler, Christopher [grundler.christopher@epa.gov]; jeffrey.girbach@daimler.com; dan.potter@daimler.com; James Hall [jamie.hall@gm.com]; Lyons, Allen@ARB [allen.lyons@arb.ca.gov]

Subject: CARB Low NOx Workgroup Meeting
Location: Exc (AN1)

Start: 5/7/2019 5:00:00 PM
End: 5/7/2019 7:00:00 PM
Show Time As: Tentative

Recurrence: (none)

Update 4/19/19

This meeting has been postponed to provide stakeholders enough time to review the White Paper.
The link to the White Paper is https://www.arb.ca.gov/msprog/hdlownox/white_paper_04182019a.pdf

Online Meeting/Conference Call Information:

https://attendee.gotowebinar.com/register/ Conference Line/Code / Ex. 6
Dial-in Number: Conference Line/Code / Ex. 6
Passcode: Conference Line/Code / Ex. 6

Meeting Purpose:

CARB staff is in the process of developing a comprehensive rulemaking that would revise various elements of the current emission regulations for on-road heavy-duty vehicles. These proposed revisions would include more stringent standards for NOx emissions, revised certification test procedures including a new supplemental low load cycle, amendments to the emission averaging, banking and trading program, amendments to warranty length and useful life periods, updated certification durability demonstration requirements, revisions to the heavy-duty in-use testing program, and revisions to warranty rate based corrective action.
To provide manufacturers with some insight going forward as they lock in designs to meet 2024 MY Phase 2 GHG standards, CARB plans to release a white paper during the week of 4/15/2019. This paper will be CARB staff's assessment of what is achievable in a cost-effective manner with engines for MY's 2024-2026, as well as 2027 and beyond.

In this meeting, CARB will discuss the content of the paper and solicit feedback from stakeholders. Also, CARB will provide an update on the proposed concepts on useful life and step 2 warranty.

Meeting Agenda:

1. Introduction (10 min)
2. CARB White Paper
   a. Presentation – 20 minutes
   b. Discussion – 40 minutes
3. Update on Proposed Useful Life and Step 2 Warranty Concepts
   a. Presentation – 20 minutes
   b. Discussion – 20 minutes
4. Next Steps (10 min)

External Attendees

SwRI, NREL, EMA, MECA, Daimler, Navistar, Paccar, Caterpillar, Cummins, John Deere, FCA US, Volvo, Hino, Ford, CTS Corp., CNH Industrial, MECA, US EPA, CEC, US DOE, ORNL, SCAQMD, , CEC, ORNL, Environment and Climate Change Canada, Taiwan EPA, ICCT, WVU, UCR, AVL, Bosch, Continental Corporation, Johnson Matthey, Corning, EnerMotion, Stoneridge, Eberspächer, Faurecia, Corning, Tenneco, BASF, Jacobs Vehicle Systems, NGK, California NGV Coalition, ATA CTA, Western States Trucking Association, Ellison Wilson Advocacy, LLC, California Fleet Solutions.

CARB Contacts

Daniel Hawelti, (626) 450-6149, daniel.hawelti@arb.ca.gov
Lee Wang, (626) 450-6145, lee.wang@arb.ca.gov

Appointment

From: Galgani, Kelcie@ARB [Kelcie.Galgani@arb.ca.gov]
Sent: 3/18/2019 9:02:34 PM
To: Galgani, Kelcie@ARB [Kelcie.Galgani@arb.ca.gov]; Grundler, Christopher [grundler.christopher@epa.gov]; Laroo, Chris [laroo.chris@epa.gov]; Heroy-Rogalski, Kim@ARB [kim.heroy-rogalski@arb.ca.gov]; Kitowski, Jack@ARB [jack.kitowski@arb.ca.gov]; Cliff, Steve@ARB [Steve.Cliff@arb.ca.gov]; Carter, Michael@ARB [michael.carter@arb.ca.gov]
CC: Robertson, Bill@ARB [bill.robertson@arb.ca.gov]; Nelson, Brian [nelson.brian@epa.gov]; Hebert, Annette@ARB [annette.hebert@arb.ca.gov]

Subject: FW: Social Event with USEPA Staff
Location: Delta King The Pilothouse

Start: 3/28/2019 1:00:00 AM
End: 3/28/2019 4:00:00 AM
Show Time As: Tentative

-----Original Appointment-----
From: Galgani, Kelcie@ARB <Kelcie.Galgani@arb.ca.gov>
Sent: Wednesday, February 27, 2019 1:37 PM
To: Galgani, Kelcie@ARB; Heroy-Rogalski, Kim@ARB; Kitowski, Jack@ARB; Cliff, Steve@ARB; Carter, Michael@ARB
Cc: Robertson, Bill@ARB; Nelson, Brian; Hebert, Annette@ARB
Subject: Social Event with USEPA Staff
When: Wednesday, March 27, 2019 6:00 PM-9:00 PM (UTC-08:00) Pacific Time (US & Canada).
Where: Delta King The Pilothouse

Appointment

From: Wang, Lee@ARB [Lee.Wang@arb.ca.gov]
Sent: 4/13/2019 2:13:36 AM
To: Wang, Lee@ARB [Lee.Wang@arb.ca.gov]; Grundler, Christopher [grundler.christopher@epa.gov]; Charmley, William [charmley.william@epa.gov]

Subject: Fwd: CARB Low NOx Workgroup Meeting
Location: Exc (AN1)

Start: 4/25/2019 5:00:00 PM
End: 4/25/2019 7:00:00 PM
Show Time As: Free

Recurrence: (none)

> So much for Steve Cliff calling me and providing me a copy of the White Paper (which wasn't going to be widely published)....

> Subject: CARB Low NOx Workgroup Meeting
>
> Online Meeting/Conference Call Information:
>
> https://attendee.gotowebinar.com/register/ Conference Line/Code / Ex. 6
>
> Dial-in Number: Conference Line/Code / Ex. 6
>
> Passcode: Conference Line/Code / Ex. 6
>
>
>
> Meeting Purpose:
>
> CARB staff is in the process of developing a comprehensive rulemaking that would revise various elements of the current emission regulations for on-road heavy-duty vehicles. These proposed revisions would include more stringent standards for NOx emissions, revised certification test procedures including a new supplemental low load cycle, amendments to the emission averaging, banking and trading program, amendments to warranty length and useful life periods, updated certification durability demonstration requirements, revisions to the heavy-duty in-use testing program, and revisions to warranty rate based corrective action.
>
> To provide manufacturers with some insight going forward as they lock in designs to meet 2024 MY Phase 2 GHG standards, CARB plans to release a white paper during the week of 4/15/2019. This paper will be CARB staff's assessment of what is achievable in a cost-effective manner with engines for MY's 2024-2026, as well as 2027 and beyond.
>
> In this meeting, CARB will discuss the content of the paper and solicit feedback from stakeholders. Also, CARB will provide an update on the proposed concepts on useful life and step 2 warranty.
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>
> Meeting Agenda:
>
> 1. Introduction (10 min)
>
> 2. CARB White Paper
>
> a. Presentation - 20 minutes
>
> b. Discussion - 40 minutes
>
> 3. Update on Proposed Useful Life and Step 2 Warranty Concepts
>
> a. Presentation - 20 minutes
>
> b. Discussion - 20 minutes
>

> 4. Next Steps (10 min)
>
>
>
> External Attendees
>
> SwRI, NREL, EMA, MECA, Daimler, Navistar, Paccar, Caterpillar, Cummins, John Deere, FCA US, Volvo, Hino, Ford, CTS Corp., CNH Industrial, MECA, US EPA, CEC, US DOE, ORNL, SCAQMD, , CEC, ORNL, Environment and Climate Change Canada, Taiwan EPA, ICCT, WVU, UCR, AVL, Bosch, Continental Corporation, Johnson Matthey, Corning, EnerMotion, Stoneridge, Eberspächer, Faurecia, Corning, Tenneco, BASF, Jacobs Vehicle Systems, NGK, California NGV Coalition, ATA CTA, Western States Trucking Association, Ellison Wilson Advocacy, LLC, California Fleet Solutions.
>
>
>
> CARB Contacts
>
> Daniel Hawelti, (626) 450-6149, daniel.hawelti@arb.ca.gov<mailto:daniel.hawelti@arb.ca.gov><mailto:daniel.hawelti@arb.ca.gov>
>
> Lee Wang, (626) 450-6145, lee.wang@arb.ca.gov<mailto:lee.wang@arb.ca.gov><mailto:lee.wang@arb.ca.gov>

Appointment

From: Bunker, Byron [bunker.byron@epa.gov]
Sent: 4/29/2019 2:15:51 PM
To: Brooks, Phillip [Brooks.Phillip@epa.gov]; Belser, Evan [Belser.Evan@epa.gov]; Grundler, Christopher [grundler.christopher@epa.gov]; Cook, Leila [cook.leila@epa.gov]; Wehrly, Linc [wehrly.linc@epa.gov]; Hebert, Annette@ARB [annette.hebert@arb.ca.gov]; Cathey, Tawanna [Cathey.Tawanna@epa.gov]

Subject: Sidley Austin Self-Disclosure
Location: C174 in Ann Arbor, Video to DC DCRoomARS1142/DC-ARIEL-RIOS-OECA-OCE, CARB via conference line

Start: 4/29/2019 3:00:00 PM
End: 4/29/2019 4:00:00 PM
Show Time As: Tentative

Conference Line: Conference Line/Code / Ex. 6
Conference ID: Conference Line/Code / Ex. 6

Message

From: Cliff, Steve@ARB [Steve.Cliff@arb.ca.gov]
Sent: 4/23/2019 10:36:12 PM
To: Grundler, Christopher [grundler.christopher@epa.gov]
Subject: Re: EMA??

Thanks

Steven S. Cliff, Ph.D.
Deputy Executive Officer
California Air Resources Board

From: Grundler, Christopher <grundler.christopher@epa.gov>
Sent: Tuesday, April 23, 2019 3:34:37 PM
To: Cliff, Steve@ARB
Subject: Fwd: EMA??

FYI

Christopher Grundler, Director
Office of Transportation and Air Quality
U.S. Environmental Protection Agency
202.564.1682 (Washington DC)
734.214.4207 (Ann Arbor MI)
Personal Matters / Ex. 6 (mobile)
www.epa.gov/otaq

Begin forwarded message:

> **From:** "Charmley, William" <charmley.william@epa.gov>
> **Date:** April 23, 2019 at 6:31:45 PM EDT
> **To:** "Grundler, Christopher" <grundler.christopher@epa.gov>
> **Subject: Re: EMA??**
>
> I went only for the first hour, and I took about 30 to 40 minutes explaining why we need ARB at these technical meetings, and that is our plan going forward.
>
> I don't have anyone from EMA (Tim French or Matt Spears) or any of the members
>
> **Deliberative Process / Ex. 5**
>
> There were a few more thoughts on this I have and I can catch up with you tomorrow.
>
> I don't know how the actual meeting went with EMA, I had never planned on going at all, and I only went for the first hour because of this issue regarding CARB participation
>
> Thanks

Bill

Sent from my iPhone

On Apr 23, 2019, at 6:15 PM, Grundler, Christopher <grundler.christopher@epa.gov> wrote:

Christopher Grundler, Director
Office of Transportation and Air Quality
U.S. Environmental Protection Agency
202.564.1682 (Washington DC)
734.214.4207 (Ann Arbor MI)
Personal Matters / Ex. 6 (mobile)
www.epa.gov/otaq

Message

From: Charmley, William [charmley.william@epa.gov]
Sent: 3/18/2019 4:43:46 PM
To: Hengst, Benjamin [Hengst.Benjamin@epa.gov]; Grundler, Christopher [grundler.christopher@epa.gov]; Desirey.Morris@arb.ca.gov; michael.carter@arb.ca.gov; Bunker, Byron [bunker.byron@epa.gov]; annette.hebert@arb.ca.gov; analisa.bevan@arb.ca.gov; jack.kitowski@arb.ca.gov; Simon, Karl [Simon.Karl@epa.gov]; mmccarth@arb.ca.gov; mark.fuentes@arb.ca.gov; mfuentes@arb.ca.gov; richard.corey@arb.ca.gov; Haugen, David [haugen.david@epa.gov]; Cook, Leila [cook.leila@epa.gov]; steve.cliff@arb.ca.gov; McCarthy, Mike@ARB [mmccarth@arb.ca.gov]
Subject: Agenda for today's Monthly OTAQ/ARB Senior Leadership Coordination
Attachments: ARB-EPA SL Call Agenda, Mar 18, 2019.docx

Dear all –

Attached is the Agenda for today's call. I have also copied this information below.
Thanks
Bill

Monthly ARB-OTAQ Senior Leadership Coordination Call
Monday, March 18, 2019 (12-1pm Pacific, 3-4pm Eastern)

Call-in number: ph Conference Line/Code / Ex. 6 Participant Passcode: Conference Line/Code / Ex. 6

Agenda Items

1. International Aircraft Particulate Matter Standards (Bill C.)

2. Highway Heavy-duty NOx rule update (ARB and EPA)

3. Other items

Upcoming Actions/Events of Interest:

- March 28: ARB/OTAQ Heavy-duty NOx meeting in Sacramento
- April 2: EPA Mobile Source Technical Review Subcommittee meeting in D.C.
- April 3-5: Society of Automotive Engineers Government-Industry Meeting in D.C.
- April 10-11 Volvo Car Company and Volvo AB meetings with OTAQ/ARB in Sweden

- May 15-16: STEPS Spring Research Symposium in Davis, CA
- July 9-12 Asilomar Conference on Transportation and Energy, Asilomar, CA
- Dec 10-11 STEPS Fall Symposium & Advisory Board Meeting & Deep Dives

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Message

From: Rashid Shaikh [RShaikh@healtheffects.org]
Sent: 4/30/2019 5:48:31 PM
To: steve.cliff@arb.ca.gov; jorn.herner@arb.ca.gov; mnichols@arb.ca.gov; Elizabeth.Scheehle@arb.ca.gov; linda.smith@arb.ca.gov; Bailey, Chad [bailey.chad@epa.gov]; Baxter, Lisa [Baxter.Lisa@epa.gov]; Bloomer, Bryan [Bloomer.Bryan@epa.gov]; Charmley, William [charmley.william@epa.gov]; Chung, Serena [chung.serena@epa.gov]; Cook, Rich [Cook.Rich@epa.gov]; Cook, Leila [cook.leila@epa.gov]; Devlin, Robert [Devlin.Robert@epa.gov]; Dunham, Sarah [Dunham.Sarah@epa.gov]; Dunlap, David [dunlap.david@epa.gov]; Dutton, Steven [Dutton.Steven@epa.gov]; Gentry, James [Gentry.James@epa.gov]; Gilmour, Ian [Gilmour.Ian@epa.gov]; Grundler, Christopher [grundler.christopher@epa.gov]; Haeuber, Richard [Haeuber.Richard@epa.gov]; Harvey, Reid [Harvey.Reid@epa.gov]; Hassett-Sipple, Beth [Hassett-Sipple.Beth@epa.gov]; Hoyer, Marion [hoyer.marion@epa.gov]; Hubbell, Bryan [Hubbell.Bryan@epa.gov]; Hunt, Sherri [Hunt.Sherri@epa.gov]; Jenkins, Scott [Jenkins.Scott@epa.gov]; Kasman, Mark [Kasman.Mark@epa.gov]; Kolb, Laura [Kolb.Laura@epa.gov]; Mazza, Carl [Mazza.Carl@epa.gov]; Miller, Andy [Miller.Andy@epa.gov]; Orme-Zavaleta, Jennifer [Orme-Zavaleta.Jennifer@epa.gov]; Owen, Russell [Owen.Russell@epa.gov]; Robarge, Gail [Robarge.Gail@epa.gov]; Robbins, Chris [Robbins.Chris@epa.gov]; Rodan, Bruce [rodan.bruce@epa.gov]; Sacks, Jason [Sacks.Jason@epa.gov]; Sargeant, Kathryn [sargeant.kathryn@epa.gov]; Sasser, Erika [Sasser.Erika@epa.gov]; Shoaff, John [Shoaff.John@epa.gov]; Simon, Karl [Simon.Karl@epa.gov]; Simon, Karl [Simon.Karl@epa.gov]; Singer, Sarany [Singer.Sarany@epa.gov]; Stanek, Lindsay [Stanek.Lindsay@epa.gov]; Teichman, Kevin [Teichman.Kevin@epa.gov]; Tsirigotis, Peter [Tsirigotis.Peter@epa.gov]; Vandenberg, John [Vandenberg.John@epa.gov]; Wehrum, Bill [Wehrum.Bill@epa.gov]; Wesson, Karen [Wesson.Karen@epa.gov]; Winner, Darrell [Winner.Darrell@epa.gov]; Woods, Clint [woods.clint@epa.gov]; Cascio, Wayne [Cascio.Wayne@epa.gov]; Keating, Terry [Keating.Terry@epa.gov]; Shaw, Betsy [Shaw.Betsy@epa.gov]; Vette, Alan [Vette.Alan@epa.gov]; michael.claggett@fhwa.dot.gov; cecilia.ho@dot.gov; april.marchese@fhwa.dot.gov; victoria.martinez@fhwa.dot.gov
CC: dgreenbaum@healtheffects.org; Robert O'Keefe [ROKeefe@healtheffects.org]; Lindy Raso [lraso@healtheffects.org]; Rashid Shaikh [RShaikh@healtheffects.org]
Subject: Sponsor Lunch and Discussion of HEI Strategic Plan 2020-2025
Attachments: First Draft HEI Strategic Plan 2020-2025 May 2019.pdf

Dear HEI Sponsors, We are looking forward to seeing many of you in Seattle at the end of the week.

In advance of the conference, we are pleased to share with you the attached first draft of HEI Strategic Plan 2020-2025. This draft highlights our recent accomplishments, the science and policy challenges going forward, and how HEI research may address some of these challenges. The research opportunities, prepared after early consultations with you, our scientific committees and the board, include many more activities than HEI can expect to accomplish under this new Plan. We very much look forward to your reactions and suggestions as we work on revising the draft by focusing on the most important research opportunities.

There will be two specific occasions during the conference when you can give us your comments. First, we invite you to a special discussion and lunch with sponsors in advance of the Conference – starting at 11:00 AM in Great Room A/B on Sunday, May 5th. Second, there will be public discussion of the Draft Plan during the meeting on Tuesday, May 7th, with time for feedback.

And, we will be happy to receive your comments in writing or over the phone in the weeks after the conference; we would hope that you could send those to us by June 4, 2019.

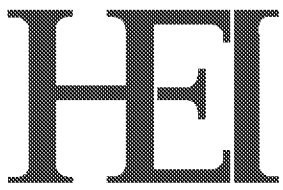
Please let us know if you have any questions.

With best wishes,

Rashid

Rashid Shaikh, Ph.D.

Director of Science
Health Effects Institute
75 Federal Street, 14th Floor
Boston, MA 02110
(617) 488-2301
rshaikh@healtheffects.org
www.healtheffects.org



Health Effects Institute

Strategic Plan for Understanding the Health Effects of Air Pollution 2020 - 2025

FIRST DRAFT

May 2019

TABLE OF CONTENTS

* *We are especially interested in comments on these major opportunities!*

INTRODUCTION AND SUMMARY

We are pleased to provide you this First Draft of the HEI *Strategic Plan for Understanding the Health Effects of Air Pollution 2020 – 2025.* HEI's success at producing trusted science to inform key decisions relies on our ability to craft this Plan every five years to review what we have accomplished, anticipate the policy and science challenges ahead, and map out the most effective way for HEI to contribute to better decisions on air quality and health. Importantly, the quality of this Plan depends on our ability to receive input from a wide variety of our audiences – our sponsors in government and industry; the scientific community; environmental and industrial stakeholders; and international, national, state and local agencies – to ensure that the HEI *Strategic Plan* targets our work at the most important topics.

We build this Plan upon the significant progress under the HEI *Strategic Plan 2015 – 2020* where, in just the first four years of implementing the plan, we have initiated, conducted, and/or completed over 50 studies, including major studies on health effects of exposure to very low levels of air pollution, new accountability and traffic related air pollution studies, to name just a few areas, and communicated our results in capitals throughout the US, Europe, and Asia. Each of our published reports – and their accompanying journal articles - have been cited in the scientific literature an average of 53 times by other scientists, and our work was cited extensively in key decision documents from US Environmental Protection Agency, the World Health Organization, the International Agency for Research on Cancer, and many more.

Looking ahead, we have already begun to identify key policy and science challenges for the coming years. We have been hearing as well from HEI sponsors and the scientific community of a number of major areas that HEI might address going forward – which at this point in Plan development includes more activities than HEI can expect to accomplish under this new Plan. ***Those major opportunities – on which we very much need your input – are described on pp. 26 to 37 and encompass four major areas of focus:***

- *Testing the Links Between Air Quality Action and Health* – building on HEI's accountability studies on key regulatory actions, exploring questions such as better methods for testing such links, whether such research help us test for causality and how they might help improve cost and benefit analyses for future actions. Studies soon to be initiated under a new Request for Applications (RFA) will address some of these questions but, given the complex nature of this issue, more research is clearly needed.
- *Complex Questions for the Air Pollution Mixture* – The difficult issues surrounding the complex air pollution mixture continue to challenge scientists and decision makers alike. HEI's Low Level Studies are testing concentration response relationships at the lowest levels and HEI's new RFA on exposure will seek and launch studies using sensors and many other new techniques to measure exposure to hard to characterize pollutants (NOx, UFP, etc.). To shed better light on the many questions that such research is raising, are there mechanistic studies needed to better understand complex exposures, and/or should HEI re-visit source-specific exposures and their differential effects? Should the health impacts of climate change, and actions to mitigate the impact of climate change, be a part of HEI's plans?
- *Transport and Urban Health* – A host of new innovations and other changes are making inroads and changing the future of transportation, even as the internal combustion engine will be in use for many years, and issues of in-use, non-tail-pipe, and other emissions continue

to arise. New questions are arising in this context, such as the health effects of ultrafine particles (UFP), as well as the role of factors such as noise, socioeconomic status, and access to green space. Anticipating the many diverse and potentially disruptive changes in transport, targeting the most significant continuing questions, and placing transport in the broader setting of urban health, will be key priorities for HEI going forward.

- *Global Health:* In the developing world, especially India and China, and elsewhere in Asia, rapid growth has raised levels of air pollution from all sources, and health science and policy decisions are just beginning to catch up to the challenge. With additional funding, HEI will continue and enhance its world-leading efforts to produce and communicate the results of Global Burden of Disease from outdoor air pollution, and produce improved science on the health effects of air pollution in developing countries, and a global analysis of the contributions to air pollution burdens from each source for every country in the world (GBD-MAPS Global).
- *A Key Cross-Cutting Issue:* Along with the opportunities mentioned above, we have identified a number of other issues that cross cut our programs. Most prominent among such issues is *Transparency in Policy-Relevant Science* – Data transparency and access are essential to the scientific process, providing insight into analytical and methodological details. Making data and analytical methods available allows others to replicate study results independently and, where necessary, perform alternative or additional analyses. As such, transparency provides equally valuable feedback to the decision-making process. Throughout its history, HEI has had a commitment to transparency and data access and maintains a strong policy on facilitating access to underlying data and methods for the studies it funds; this will be a hallmark of the HEI Strategic Plan 2020 - 2025. Other cross cutting issues – such as better statistical methods, susceptible populations, enhanced exposure assessment and capacity building – will continue to be an important part of HEI research and review activities.

While the *HEI Strategic Plan* is designed to be a clear path forward for us to follow in the coming years, we have found that, in order to be as responsive as possible to the emerging needs of our sponsors and others, we must as well build in the flexibility to *anticipate and act on the unanticipated*, and fully expect to continue to have that capacity in the coming years.

All told, these important areas cover a wide range of topics for which HEI's intensive research and special review capabilities could provide credible and policy-relevant answers. However, to help us sift through these possibilities systematically, and identify the most critical priorities for our *Strategic Plan 2020 - 2025* we need the input of the wide range of audiences we serve. We welcome your comments at a special session of our Annual Conference in Seattle, WA, on Tuesday, May 7, 2019 (see www.healtheffects.org/annual-conference for details). And please forward any further comments you may have to HEIplan@healtheffects.org.

PROGRESS: HEI STRATEGIC PLAN 2015–2020

PRIORITY RESEARCH AREAS

The *HEI Strategic Plan for Understanding the Health Effects of Air Pollution 2015 – 2020,* issued in April 2015, identified four major priority research areas: multipollutant science, accountability and transparency, emerging fuels and technologies, and global health science. In addition, HEI identified cross-cutting issues that apply across all research areas, including new statistical methods, susceptible populations, other health outcomes and modifying factors, mechanisms and capacity building.

Multipollutant Science

HEI entered the last Strategic Plan having completed several major studies on multipollutant exposures and health effects, including those focused on a better understanding of health effects from different PM components and sources (NPACT), improved statistical methods, air pollution from traffic sources, and others. While the need for research on many of these topics continued, new scientific challenges were also identified during development of the new plan in 2014. Thus, Strategic Plan 2015-2020 focused on research on the effects of exposure to very low levels of air pollution, potential cardiovascular and respiratory effects of low levels of ozone exposure, exposures and health effects from traffic and port sources, and a new review of the literature on the health effects from exposure to traffic related air pollution.

Emerging Technologies and Fuels

HEI has since its inception played a role in assessing new fuels and technologies. With the introduction of a variety of new fuels and technologies, interest in such developments is high, especially given their implications for climate change, as well as conventional pollutant emission reductions. HEI's new Plan proposed several areas of evaluation and potential research, including potential impact of the introduction of ethanol and gasoline direct injection, emissions of ultrafine particles and non-tail-pipe emissions (such as tire and brake wear).

Accountability and Transparency

HEI has provided a lead role in accountability research, further defining concepts and methods and initiating the next stage of new research in this challenging field examining the air quality and health impacts of actions to improve air quality. Having completed a substantial body of research, HEI built on the lessons learned from those studies through critical review, publications, and collaborative efforts to identify and exploit new methods. Strategic Plan 2015-2020 posited completion of several studies funded under phase 2, which built on and extended beyond opportunistic studies of shorter-term interventions to address larger regulatory programs implemented over longer periods of time. To accomplish this, the HEI program included research on enhanced analytical methods and the more systematic linkage of accountability studies to the adoption of major new regulatory initiatives. HEI also extended its ongoing work on transparency and data access during this Plan.

Global Health Science

HEI built on key themes of accountability, multipollutant approaches and research at the air quality–climate nexus through competitive selection of proposals from among the leading scientists in many countries of the world to fund research that informs decisions in North

America, Europe, and Japan. The resulting HEI science is both domestically and globally relevant and has been regularly called upon to credibly inform decisions affecting public health and potential regulation in key forums in the developed and developing worlds. With added support from foundations, international sponsors, and in partnership with the European Union and others, HEI selectively enhanced its research program in the developing economies of Asia and Latin America, including support for global burden of disease from air pollution, source specific health impacts, life expectancy and other long term trends in worldwide air pollution and health.

ACCOMPLISHMENTS

MULTIPOLLUTANT SCIENCE

Estimating the Effects of Exposures to Low Levels of Air Pollution

Multipollutant Studies in Large Populations to Estimate the Effects of Exposure at Low Concentration

In the first years of the 2015-2020 Plan, HEI initiated a comprehensive program of three critical studies to characterize the potential health effects from long term exposure to low levels of air pollutants. HEI undertook this program after some epidemiologic studies reported adverse health effects even at levels lower than the U.S. National Ambient Air Quality Standards (NAAQS). Following an expert workshop in mid-2014 and an RFA issued later that year, HEI decided to fund three studies, engaging highly qualified multi-disciplinary investigator teams to examine air pollution and health relationships in very large cohorts in North America and Europe. The three studies are:

- **Michael Brauer**, University of British Columbia, Vancouver. *Identifying the shape of the association between long-term exposure to low levels of ambient air pollution and the risk of mortality: An extension of the Canadian Census Health and Environment Cohort using innovative data linkage and exposure methodology.* This study is testing and extending analyses in Canadian cohorts where data on residential address and other confounders (smoking status, income, etc.) are available; total cohort size ~ 6 million.
- **Bert Brunekreef**, University of Utrecht, the Netherlands. *Mortality and morbidity effects of long-term exposure to low-level $PM_{2.5}$, black carbon, NO_2 and O_3: an analysis of European cohorts.* This study is conducting a pooled analysis in key populations from the European ESCAPE study, and companion analyses in six large administrative cohorts, with a total population size of approximately 25 million; and,
- **Francesca Dominici**, Harvard T.H. Chan School of Public Health, Boston. *Assessing adverse health effects of long-term exposure to low levels of ambient pollution, including development of methods for methods for causal modeling.* This study is conducting detailed and innovative analyses in the U.S. Medicare cohort, with a population size of over 65 million, with additional analyses in the Medicaid cohort and the Medicare Current Beneficiary enrollees cohort.

The strengths of the HEI program include:

- Application of HEI's well developed methods for study oversight, with a special oversight panel, and QA/QC audits, performed by an independent contractor.
- HEI's rigorous and in-depth review and evaluation, including comprehensive comments, by an expert Review panel upon completion of the studies.

- Very large populations with millions in the US, Canada and Europe, thus giving the studies an unprecedented statistical power.
- State of the art methods for exposure assessment, at high spatial resolution (1 km^2 or address level) using satellite data, chemical transport models, land use and weather variables and monitoring data, for fine particulate matter ($PM_{2.5}$), ozone, nitrogen dioxide (NO_2), and PM components, such as BC and non-tailpipe PM indicators in a subset.
- A wide range of mortality and morbidity health outcome, including all cause and cause-specific mortality, lung cancer incidence and cause-specific hospitalization.
- Development and application of new statistical methods, allowing for systematic side-by-side comparisons with traditional analyses methods. Areas of refinement include methods to adjust for exposure measurement error, alternative ways to adjust for confounding and effect modification, and use of causal modeling techniques.
- Opportunities to apply the same or similar methods for exposure assessment in different geographical areas, for comparison among different approaches.
- Highly experienced, multi-disciplinary investigator teams with extensive experience in cutting-edge research in exposure assessment, environmental epidemiology and statistical analysis.

The US and Canadian studies are 60 – 70% complete whereas the European study is nearly 80% complete. We anticipate final reports from the studies arriving at HEI during early part of the new plan; after review and commentary preparation, the research reports to be published in the early years of the new Strategic Plan.

While more detailed analyses are in progress, both the US and Canadian teams have published early results from their work in peer-reviewed journals. Given the importance of these studies – both scientifically and in the context of public policy – HEI requested the two teams to submit Phase 1 reports, comprised of their analyses, results and conclusions from the first two years. HEI has formed a multi-disciplinary expert panel to review these Phase 1 reports and to prepare a commentary, discussing the research and the conclusions that may be drawn – which are expected to be further refined by continuing work. The investigators Phase 1 reports and the review panel's commentaries are expected to be published during summer, 2019.

Effects of Low Levels of Ozone on the Cardiovascular System

Studies on the acute effects of ozone have largely focused on pulmonary effects – indeed, such effects are the basis for the current ozone NAAQS – and effects on the cardiovascular system have not received similar attention. Several epidemiological studies that included assessment of associations with specific causes of death have reported some associations of ambient exposures to ozone with cardiovascular mortality. In 2011, HEI initiated the **M**ulticenter **O**zone **S**tudy in Old**E**r **S**ubjects (**MOSES**), the largest and most rigorous study ever conducted to investigate whether short-term exposure of older, healthy volunteers to near-ambient levels of ozone in a controlled exposure setting induces acute cardiovascular responses. The MOSES investigators tested 87 subjects at two levels of ozone (70 and 120 ppb) and clean air as control. The three investigators and their centers where the laboratory work was carried out were:

- **John Balmes**, University of California San Francisco Medical School,
- **Phil Bromberg**, University of North Carolina Medical Center, Chapel Hill, and

- **Mark Frampton**, University of Rochester Medical School, New York.

In June 2017, HEI published a comprehensive report prepared by the multicenter team, which described the study and its findings in depth. HEI formed a special panel which reviewed the report and its conclusions, and its commentary was published with the report. Additionally, HEI made provisions for full access to MOSES data to interested scientists and analysts; the data along with descriptive files are available from the Harvard Dataverse (https://dataverse.harvard.edu/). A small number of unused biological samples from the study were also made available.

In late 2017, HEI engaged the MOSES investigators to perform additional data analyses to examine whether any effects could be demonstrated from prior exposures (i.e., hours and days before experimental exposures at the laboratory). The report from the latest analyses is currently being reviewed by the MOSES review panel and the report, along with the panel's commentary, will be published in late 2019.

Examining Exposures and Health Effects from Traffic and Port Source Mixtures

Completion of Exposure Studies Previously Undertaken

Despite significant progress in the control of tail-pipe emissions from mobile sources, and a general reduction in ambient air pollution levels, populations continue to live close to major roads and highways and are thus exposed to emissions from vehicle traffic that may have adverse effects on their health and well-being. In 2010, HEI published a comprehensive review of the literature on the health effects of traffic related air pollution. Among other research needs, the review identified a paucity of reliable information on human traffic exposure as a major gap in knowledge.

Initiating a new research program on traffic-related air pollution, HEI funded five studies to improve exposure assessment to traffic-related air pollutants, and additional studies of non-tailpipe emissions (such as brake and tire wear) near roadways and a study of air pollution in tunnels. Three of these studies have been published (**Ben Barratt, Jeremy Sarnat, Xiaoliang Wang**), while two others -- **Stuart Batterman and Chris Frey** – are in the midst of the review process. Two studies on non-tail pipe emissions -- **Petros Koutrakis and Meredith Franklin** – are ongoing.

Launching a New Research Program

Given the potential importance of traffic related air pollution, as well as the increasing recognition that the effects of such exposures are also influenced by noise, socio-economic status, and access to green space, HEI issued another RFA in 2017 to fund studies linking traffic exposure to health, including the impact of noise and SES. HEI is now funding three additional studies (**Payam Dadvand and Jordi Sunyer; Meredith Franklin; Ole Raaschou-Nielsen**). Work on each of these studies is underway.

Diesel Emissions and Health Effects

Early during Strategic Plan 2015-2020, HEI published and widely disseminated two reports: HEI Special Report 19, *Diesel Emissions and Lung Cancer: An Evaluation of Recent Epidemiological Evidence for Quantitative Risk Assessment*, and the *Executive Summary of The Advanced Collaborative Emissions Study (ACES)*. The first report was prepared by a special panel appointed by HEI to closely examine and evaluate the findings of the then recent studies in miners and truckers, each group exposed to emissions from old technology diesel engines. The second report was a comprehensive and succinct summary of an extensive HEI program – *the Advanced Collaborative Emissions Study (ACES)* – whose goal was to characterize emissions from new technology diesel engines, model year 2007 and 2010, designed to meet the new stringent standards, and to test for health effects in an

animal model. HEI presented – and continues to present - the findings of both reports at many major national and international meetings and symposia as well as to governmental bodies.

Review of the State of Knowledge Regarding Health Effects of Traffic-Related Air Pollution

Since publication of HEI's 2010 critical review of the literature on traffic related air pollution and health, a large number of additional studies have been published and regulations and vehicular technology have advanced significantly. The topic continues to be of public health interest and is of concern to policy makers and motor vehicle manufacturers alike. During preparation of the 2015-2020 Strategic Plan, sponsors encouraged HEI to update the previous literature review. Therefore, in 2018 HEI formed a new panel of scientists with expertise in exposure assessment, epidemiology, and biostatistics and charged with evaluation and synthesis of the associations of long-term exposure to traffic-related air pollution and the epidemiologic evidence for selected health outcomes, keeping in perspective the influence of other factors such as noise, SES and green space. The panel consists of the following members:

- Francesco Forastiere, Co-Chair (King's College London, UK)
- Frederick Lurmann, Co-Chair (Sonoma Technology, Inc., Petaluma, CA)
- Richard Atkinson (St George's, University of London, UK)
- Jeffrey Brook (University of Toronto, Canada; Member Research Committee)
- Howard Chang (Emory University, Atlanta)
- Gerard Hoek (Utrecht University, Netherlands)
- Barbara Hoffmann (University of Düsseldorf, Germany; Member Research Committee)
- Sharon Sagiv, University of California, Berkeley
- Audrey Smargiassi (University of Montreal, Canada)
- Adam Szpiro (University of Washington, Seattle)
- Danielle Vienneau (University of Basel, Switzerland)
- Gregory Wellenius (Brown University, Providence)
- Jennifer Weuve (Boston University, Boston)

The panel began its work in mid-2018, and has developed a protocol, risk-of-bias tool, and other instruments for its review; it has now begun literature searches and data extraction. Intensive work continues during 2019, with the report expected to be published, after peer-review, in late 2020.

Enhancing Exposure Assessment

Launching a New Research Program

Recognizing the challenges of accurately estimating exposures to a range of air pollutants whose exposure – especially long-term exposure - has been difficult to characterize, HEI has recently issued RFA 19-1, titled *Applying Novel Approaches to Improve Long-Term Exposure Assessment of Outdoor Air Pollution for Health Studies.* The RFA is focused specifically on exposure assessment of outdoor air pollutants whose levels vary greatly in space and time, such as nitrogen oxides, ozone, and ultrafine particles. Applications are expected in 2019, with studies to begin in early 2020.

ACCOUNTABILITY AND TRANSPARENCY

HEI has continued its strong leadership in developing and funding innovative research on accountability during 2015-2020.

Completion of Studies Previously Undertaken

Major accomplishments include the completion of four studies from the second wave of accountability (or health outcomes) studies, focused on long-term actions to improve air quality at a regional and national level, assessing actions targeted at major ports, and improving statistical methods:

- Published reports on: Causal inference methods for estimating long-term health effects of national air quality regulations by **Corwin Zigler** (May 2016), the effects of policy-driven air quality improvements on children's respiratory health in Southern California by **Frank Gilliland** (January 2017), and impacts of regulations on air quality and emergency department visits in the Atlanta Metropolitan Area, 1999–2013 by **Armistead Russell** (April 2018).
- After completion of a pilot phase, a fourth study on improvements in air quality and health outcomes among California Medicaid enrollees due to goods movement actions in California by **Ying-Ying Meng** will be completed in Spring 2019 (publication expected in 2020).

In addition, HEI supported accountability-related research through other programmatic initiatives:

- A study to quantify mortality benefits of transportation emission reductions in the United States and Canada by **Amir Hakami** was funded in the Summer of 2018 through an open research solicitation.

Leadership Role in Developing Research in Accountability

In addition to funding research studies, HEI continues to engage in other activities that include leadership by publishing literature reviews (listed below) as well as organizing conference symposia, and participation in research planning activities:

- *Accountability Studies on Air Pollution and Health: the HEI Experience* in Current Environmental Health Reports, 2017 (4):514-522, by **Boogaard, van Erp, Walker, and Shaikh**
- *Assessing health effects of air quality actions: what's next?* In Lancet Public Health, Vol 4 January 2019, by **Boogaard** and **van Erp**
- Cochrane Review: *Interventions to reduce ambient particulate matter air pollution and their effect on health (Protocol)* by Burns, **Boogaard**, Turley, Pfadenhauer, **van Erp**, Rohwer, and Rehfuess. 2019. DOI: 10.1002/14651858.CD010919.pub2. This work also presented in several poster sessions at various conferences, including WHO workshops on Air Quality Guidelines

Launching of Next Generation Accountability Studies

In view of ongoing strong interest by sponsors and others in the scientific community, HEI issued RFA 18-1, *Assessing Improved Air Quality and Health from National, Regional, and Local Air Quality Actions*, in December 2018 to solicit a third wave of accountability studies. Twenty-eight preliminary applications were received in February 2019. Ten applicants were invited to submit a full application for a funding decision in the Summer of 2019.

Data Access and Transparency

Throughout its history, HEI has had a commitment to transparency and data access. HEI fosters transparency by encouraging researchers to make their data available to the public, as long as any data confidentiality agreements are not breached. Regularly, investigators are asked to share statistical code and other details of their analyses during the HEI review process for their studies.

Recent examples of public access to data generated during HEI studies include (for full details and list of older studies, visit *www.healtheffects.org/research/databases*:

- **Francesca Dominici** and her colleagues, who are conducting the US study on effects of low levels of air pollution, are have efforts underway to provide access to their data and analytical methods (health data used in these studies, obtained from Medicare and Medicaid Services, cannot be made public in compliance with federal regulations).
- Data from the ***Multicenter Ozone Study in Older Subjects*** **(MOSES)** at the Harvard Dataverse (https://dataverse.harvard.edu/)
- Data sets from the **Wang** study, containing information on real-world emissions in two traffic tunnels in Hong-Kong and Baltimore, at the Harvard Dataverse (https://dataverse.harvard.edu/),
- Data from emissions characterization under the **HEI Advanced Collaborative Emissions Study (ACES)** can be obtained from the website of HEI's partner, the Coordinating Research Council, for Phase 1 https://www.crcao.org/reports/recentstudies2009/ACES%20Phase%201/ACES_Final_Database_JUNE2010.zip and for Phase 2 https://www.crcao.org/reports/recentstudies2013/ACES%20Ph2/Database%202013.12.16.zip.
- HEI also maintains a number of other data bases that are available through our website (*www.healtheffects.org/research/databases)*

EMERGING FUELS AND TECHNOLOGIES

HEI has long provided critical information on key emerging questions relevant to vehicles and fuels, and HEI's goal is to continue to provide such time-sensitive information on the full range of emissions and effects of new technologies and fuels that are being driven by climate, energy efficiency and air quality.

Regarding fuel composition and PM emissions, HEI organized a workshop in 2016, with the goal to present the latest information on the impact of ethanol and aromatics in fuel, the use of gasoline direct injection, and the challenges to meeting the latest US and California standards. HEI published an Executive Summary of this workshop which highlighted the salient findings of presentations and discussions during the workshop.

Ultrafine particle (UFP) emissions and their potential impact continue to be an area of interest and measurements and effects of ultrafine are a part of several HEI studies. The abovementioned workshop on fuel composition and PM emissions also included useful information on UFP emissions. As discussed above, HEI has recently issued RFA 19-1, titled *Applying Novel Approaches to Improve Long-Term Exposure Assessment of Outdoor Air Pollution for Health Studies*. The RFA is focused, among other pollutants, on ultrafine particles.

Non-Tail Pipe Emissions As the use of diesel particulate filters, and other technologies, decreases the overall emissions of PM from the tailpipe, non-combustion emissions of PM are receiving more attention, for example, dust from brake and tire wear and resuspended road dust. Such emissions have not been well studied or characterized. HEI has funded two studies in this area and may undertake additional research in the future.

- **Petros Koutrakis** (Harvard Chan School of Public Health), Chemical and physical characterization of non-tailpipe and tailpipe emissions near major roads in the Boston Area,

and

- **Meredith Franklin** (University of Southern California), Intersections as hot spots: Assessing the contribution of localized non-tailpipe emissions and noise on the association between traffic and children's health.

GLOBAL HEALTH SCIENCE

In the context of sustained interest and demand for HEI science in its core domestic arena, HEI has worked systemically and carefully to extend the scope of its science to be globally relevant by obtaining supplemental support from a range of philanthropic, governmental, industrial and banking sources. This funding leverages core funding to enable HEI to support a broad portfolio of science.

HEI's global program includes studies reported earlier in this plan that are directly relevant to research questions and decisions in the United States, Europe and Japan, areas where complex mixtures of lower levels of many air pollutants, advanced technologies, accountability, traffic exposures, methods development, and causality are of primary concern. This work is often undertaken in partnership with or to inform decisions by WHO (Global Air Quality Guidelines for major pollutants), and the European Commission (European Limit Values for $PM_{2.5}$, NO_2, CO and some air toxics) and effectiveness of air quality actions and regulations, and these same studies are designed to also inform decisions in the United States.

In the developing world, supplemental foundation funding from HEI's global program has supported a diverse program of air pollution science and communication, including developing Asia with a focus on China and India, parts of Eastern Europe, Africa, and Latin America where air pollution levels and public health impacts from ambient and in some regions, household sources are exceedingly high and often increasing.

Taking a global perspective uniquely positions HEI to inform understanding of health effects along the entire exposure response spectrum, have a policy impact in highly polluted highly populated areas, and provide science to inform regulatory decisions at the source, providing air quality benefits to local populations, reducing transport to Japan and North America, and providing a health based rationale for moderating greenhouse gas production in developed and developing countries.

Supporting broadly relevant studies in Europe

As reported in detail earlier, from 2015-2020, HEI has initiated or completed a range of studies in that directly inform decisions in the United States in priority research areas of multi pollutant science, emerging technologies and fuels, and accountability, even as they contribute to local knowledge. Representative examples in the global arena include:

- A study of low-level effects of ambient air pollution and mortality in large cohorts by **Bert Brunekreef** and colleagues in Europe, with results expected for HEI review and publication in the first years of the new Strategic Plan;
- A study of exposure and health effects from traffic by **Xiaoliang Wang** evaluating how mobile-source emissions have changed by examining real-world emissions characterization in the Shing Mun Tunnel in Hong Kong and the Fort McHenry Tunnel in Baltimore, Maryland;
- A study that developed a dynamic three-dimensional land-use regression model for Hong Kong and used it to estimate exposure to traffic-related air pollution at ground level and upper elevations in urban areas by **Benjamin Barratt**.

Results of these and companion studies have been and will continue to be actively communicated in key European and globally relevant forums and scientific workshops, including at WHO, DG Environment, IARC, and to national governments as they consider evaluation of European limit values, national emission ceilings, and standards for stationary, mobile sources and other sources which, in turn, provide guidance to many developing countries as well.

Developing countries

In the developing world especially India, China, and elsewhere in Asia, rapid growth has raised the level of air pollution from all sources, yet health science is often lagging, limiting the ability to address this problem. HEI leveraged significant additional funding from foundation and other sources to provide key science, capacity building and communication in developing countries where levels of air pollution consistently exceed health based international and national standards.

HEI engagement is based on its experience that local health impacts, credibly presented and understood in a global context provides multiple benefits, including credible science to inform decisions in the emerging vehicle and technology markets, high quality health-impact information and source specific health effects to guide informed air quality management and mitigation of emissions in Asia, reducing air pollution transported to Japan and the Western US. At the same time HEI has built capacity and fostered international cooperation by working with leading scientists and institutions in key parts of the developing world side by side with leading western investigators.

Key results from HEI's global program include:

Support for the Global Burden of Disease (GBD), the most comprehensive and credible worldwide assessment of all major risk factors associated with death and disease. Now produced annually, GBD is produced by the Institute for Health Metrics and Evaluation. HEI and our partners provided leadership the air pollution analysis for all GBD releases from 2015-2020 and worked with IHME and others to communicate country global and country specific impacts to national policy makers and stakeholders.

GBD's 2017 report, published in the Lancet, relied on updated data and methods to identify air pollution as the 5th highest ranking risk factor for mortality worldwide, behind measures of only diet, blood pressure, tobacco and blood sugar. For the first time, air pollution impacts were calculated including the addition of diabetes as a key health outcome and will be further expanded in coming editions.

Source Specific Impacts of Air Pollution The developing world faces significant limitations on air monitoring and health data and, as a result, information on source specific health impacts. Such information is key to educating the public about key sources and enabling regulators and stakeholders to make informed choices about health-based air quality management, now and projecting into the future to evaluate business as usual relative to alternative scenarios. Over the past 5 years, HEI has brought together leading scientists and institutions from China (Tsinghua University) and India (IIT Bombay) with experts from Canada and the US to publish:

- *GBD MAPS – China*, which identified emissions from the industrial, energy and domestic coal as a concern now and looking forward, and
- *GBD-MAPS – India*, which found residential biomass anthropogenic dusts and coal as sources with major health impacts.

State of Global Air During the last 5-year strategic plan, with supplemental funding, HEI conceived, published and widely communicated a new flagship annual publication and website *State of Global Air* (SoGA). SoGA is a unique resource that builds on the annual GBD to report on the levels and

burden of air pollution for every country in the world, in some cases providing data at the provincial level (e.g. China) in a current, searchable database. SoGA provides data on levels of air quality in each country mortality impacts from major diseases impacted by air pollution, and air pollution and mortality trends from 1990 through 2017, providing the ability to track progress (or lack thereof) on a country specific, regional and global level.

SoGA was also designed to report on key studies beyond only GBD, including results from WHO, IEA, World Bank and other analysts, enhancing understanding of differences and similarities in methods and results worldwide in a single location.

- SoGA 2017: Introduced data on the significant global mortality impact of air pollution and worldwide and those regions that are most and least affected
- SoGA 2018: Updated the above information and focused in depth on tacking trends in India and China, and the significant burden of household air pollution
- SoGA 2019: Provided new information on life expectancy, the addition of diabetes as a risk factor and signaled progress in China with initial declines in air pollution.

As with all HEI reports, results are communicated to national decision makers in partnership with leading local health and academic partners to help ensure credibility.

Building a Stronger Scientific Base While many results of studies in other parts of the world can be applied in estimating health burden of air pollution, the acceptance of those estimates can be enhanced by attempting to produce selected additional studies for key questions, e.g. estimating health burdens at high ambient levels. To that end, HEI in 2017 funded a team led by **Roel Vermeulen**, et al that is applying air pollution exposure estimates to pre-existing and well characterized population cohorts in a number of Asian cities.

CROSS-CUTTING ISSUES

Many studies mentioned in the previous sections address cross-cutting issues, including advancing statistical methods, at risk populations, other health outcomes and modifying factors, enhanced exposure assessment, mechanistic studies, and capacity building. Accomplishments during Strategic Plan 2015-2020 include:

- Studies to *advance statistical methods* to more accurately understand and interpret data from epidemiological studies (Molitor, Park, Zigler, Coull, Batterman). Additionally, under the HEI program on health effects of exposure to low levels of air pollutants, several new methods are being developed, targeted at refinements to methods for exposure assessment and causal inference (Brauer and Dominici).
- Laws to improve air quality in many countries frequently call for protection of *susceptible populations.* HEI supported studies in this area include research in the young (Gilliland), pregnant women (Lee, Qian, Wu) and the elderly (MOSES), and in individuals with asthma (Pedersen).
- *Enhanced exposure assessment*, as discussed above, is a key component of many HEI studies (for example, the exposure to low-levels of air pollution and traffic studies) and HEI investigators are developing and applying advanced techniques, using data from satellite data, chemical transport models, land use and weather variables and monitoring data, for state-of-the-art exposure assessment at wide geographical scales. In addition, HEI has funded other research to improve exposure assessment and has just issued an RFA focused specifically on exposure assessment of outdoor

air pollutants whose levels vary greatly in space and time, such as nitrogen oxides, and ultrafine particles.

- Studies examining *other health outcomes and modifying factors,* including reproductive effects and pregnancy outcome (Dadvand, Wu, Qian, Molitor); neurocognitive outcomes (Chen) and autism (Guxens), as well as noise (Franklin, Raaschou-Nielsen) and socio-economic factors (Clougherty, Raaschou-Nielsen).
- Studies focused on *mechanisms* that are important in forming and transforming air pollutants in the atmosphere (Surratt; Ng), or in producing toxicologic effects (Contreras, Fryer, Gowdy, Shiraiwa).
- *Capacity building*, by supporting early-career investigators to focus their research on environmental health issues; since 2015, HEI has funded five such investigators under its prestigious Rosenblith Award, including Gowdy, Guxens, Apte, Pedersen, and Shiraiwa.

MEASURING HEI'S IMPACT

IMPACT ON SCIENCE

HEI focuses its efforts to ensure that the science it produces is both relevant to decisions and advancing understanding across the scientific community. HEI is also strongly committed to tracking the Institute's progress in meeting these goals is. HEI initiated and completed a large number of projects that were undertaken to implement the HEI Strategic Plan 2015 – 2020. Beyond these activities, however, HEI regularly examines other measures to assess how effective HEI's work has been in informing both our scientific and policy audiences. The results of our review of these measures is summarized below.

Studies Started and Completed

HEI initiated 21 studies of air pollution health and exposure over the first four years of the 2015-2020 Strategic Plan and published 30 reports. This number includes several reports that were large, complex, and multipart (such as the MOSES report). HEI published five communications and special reports, including publications focused on Diesel Epidemiology and China and India source-specific burdens. At the start of the last year of the Plan, HEI has six reports in its review and publication process (including MOSES Part II and Phase 1 reports from the Dominici and Brauer low level exposure studies). HEI also maintains data from key studies at publicly accessible websites and, from time to time, other air pollution data.

Study Dissemination

Since its inception, HEI has distributed scientific reports and summaries of those reports (HEI Statements) to a growing list of HEI sponsors, scientists, and interested parties in government, environmental organizations, and industry. Between 2015 and 2019, HEI distributed more than 2,000 research Reports and nearly 12,000 HEI statements. All HEI reports are also available online through *www.healtheffects.org/publications*. Our website has proved to be an increasingly effective means of extending HEI's reach. Website downloads may be the best measure of the value of HEI publications, because downloading is an active process undertaken by people who think a report may be of value. HEI has seen substantial and increasing distribution of its scientific documents via the Web. Each year, the HEI website is visited by more than 35,000 visitors, who viewed more than 145,000 web pages and downloaded some 29,000 Research and Special Reports, HEI Statements, and other documents. In addition, HEI's new State of Global website attracted 15,000 visitors in its first year and 27,000 in the second year, with around 6,000 report and figure downloads in both years. So far, 2019 is showing similar trends.

Citation of HEI Reports in the Scientific Literature

Another measure of HEI's impact is the extent to which the scientific community reads and uses its scientific reports. HEI recently analyzed the extent to which HEI Research Reports and scientific papers resulting from HEI supported work, published in 2015 through April 2019, have been cited in the scientific literature. Results of this analysis suggest that HEI's impact is substantial (Figure 1).

- The 30 HEI reports published through Year Four of the Plan were cited 169 times in more than 50 health and atmospheric science journals (since some of those reports were only published recently, we would expect citations to rise in the coming years).
- The work described in the 30 reports also resulted in 59 peer-reviewed scientific articles; these

peer-reviewed publications, in turn, were cited 1426 times in other publications.

- Thus, the 30 HEI-funded research reports during 2010-2014 generated an average of 53 citations per report (citations of the original report and its related journal articles), an extraordinarily high number of citations for any scientific work. Note that these data do not include the 23 studies that are currently in progress and their peer-reviewed publications, nor does it include HEI reports and publications prior to 2010 which continue to be cited.

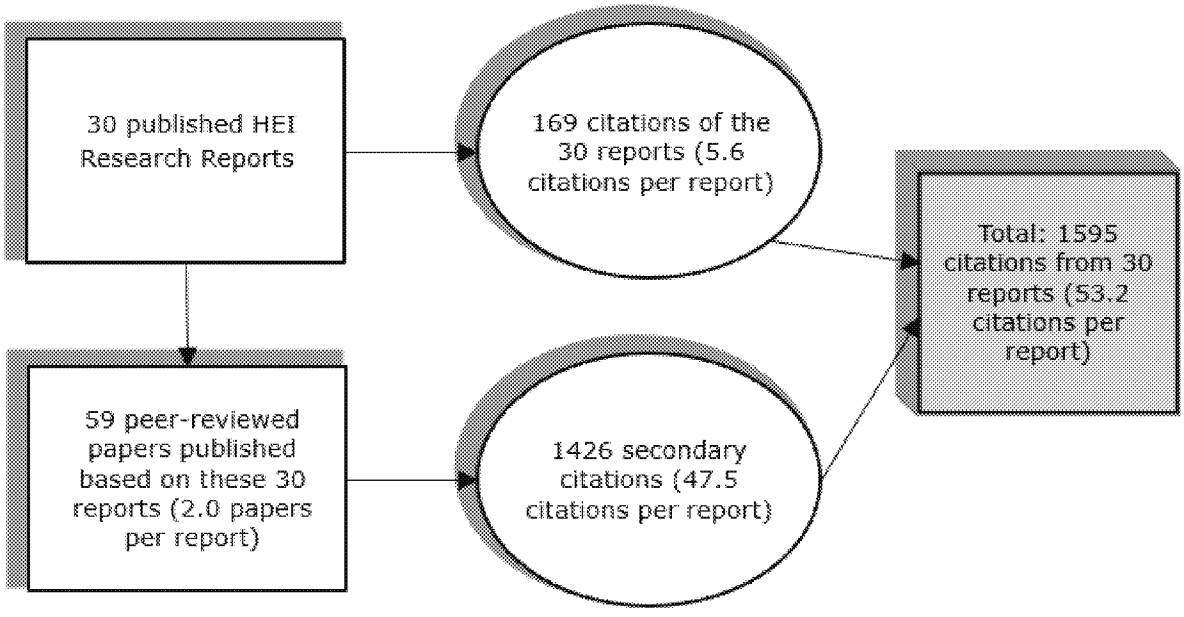


Figure 1: Citations of HEI reports (published during 2015 - 2019) and accompanying journal articles in the scientific literature. *(Numbers in parenthesis are average per report).*

IMPACT ON POLICY

The full measure of HEI's effectiveness must include some consideration of how well the science it produces is communicated and put to use in decision making.

Similar to the citation counts in the scientific literature, how often HEI reports are cited in regulatory documents can help gauge our impact. By this measure, HEI has significantly contributed to the scientific basis of norms, standards and guidelines, in the US and elsewhere. For instance, Figure 2 illustrates a continuing role in the EPA's last four reviews of the particulate matter ambient air quality standards. And this impact is likely significantly understated, as it only includes actual HEI reports cited in the ISA; as noted above, for each HEI report there are at least two journal papers produced as well whose citation in the ISA is not counted in Figure 2. Equally significant is the fact that HEI's reports are also cited in the most recent assessments done for each of the other criteria pollutants as well.

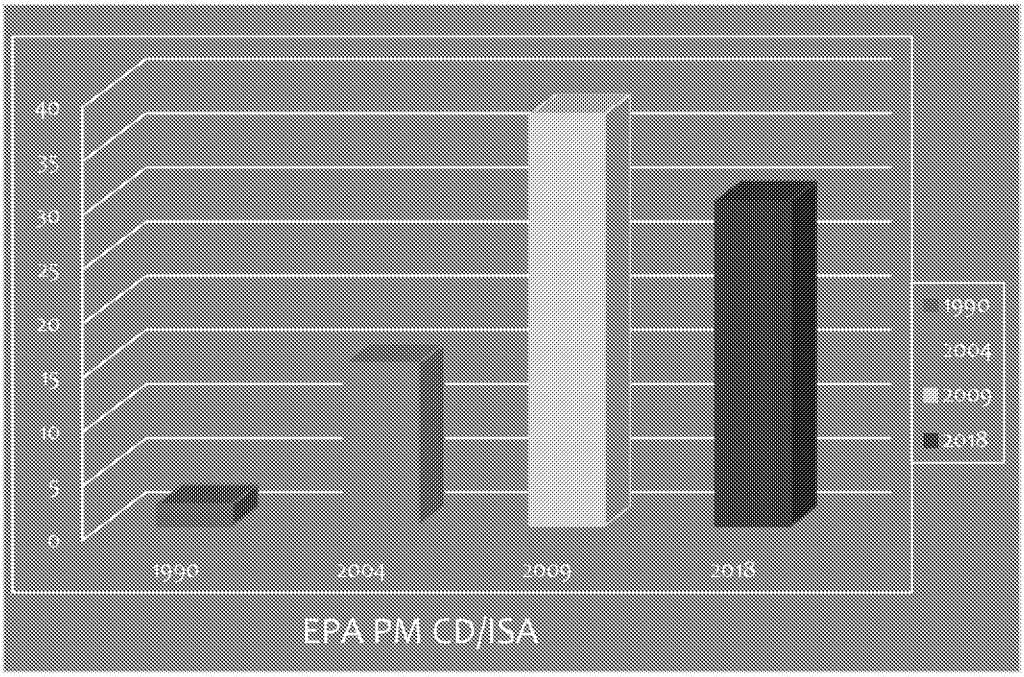


Figure 2. Citations of HEI reports in Key US EPA Scientific Summaries

(Note: the 2018 EPA document is a draft and not the final ISA).

Communication does not end, of course, with the citation of an HEI report in a regulatory document. HEI engages in *frequent outreach to leadership and staff from EPA and core industry sponsors,* and is often invited to share its science and expertise with a wide set of other public and private actors shaping environmental and public health policy on air pollution. Since 2015, HEI has presented information, provided testimony, and offered technical advice and other assistance in many settings, for example:

- *US Governmental agencies and legislative bodies:* The U.S. Congress; Federal Highway Administration, National Institutes of Health, Occupational Safety and Health Administration, Department of Energy, California Air Resources Board;
- *Public and private advisory bodies:* The National Academies of Science, Engineering and Medicine; Clean Air Act Advisory Committee; Mobile Sources Technical Review Subcommittee;
- *International organizations and agencies of foreign governments:* The European Commission; European Parliament; World Health Organization; International Agency for Research on Cancer, World Bank; the UK Committee on the Medical Effects of Air Pollution; China Ministry of Ecology and Environment (including the annual Air Benefit and Cost and Attainment Assessment (ABaCaS) Meetings); India Ministry of Environment, Forests and Climate Change;
- *Private sector associations and public interest groups:* American Forest and Paper Association; American Lung Association; American Petroleum Institute, CONCAWE; Auto Alliance; ACEA; Engine Manufacturers Association; Environmental Defense Fund; European, US, and Indian Emission Control Manufacturers; Natural Resources Defense Council; Union of Concerned Scientists.

THE CHALLENGES AHEAD: The Policy and Science Context

POLICY CHALLENGES

Identifying the highest priority needs and concerns of air pollution policymakers is a critical element in HEI's research planning. While it is clear that air quality goals remain a significant focus of public interest and heated debate in the U.S. and globally, new health concerns and an increasingly complex energy landscape are challenging established air pollution strategies and raising new research priorities. This is apparent in a broad range of recent and ongoing regulatory reviews and other policy-setting activities which stress issues such as: potential unaddressed human health impacts, even at very low pollutant concentrations; characterizing exposures in highly localized environments; and the health of children and other sensitive populations. In addition to further studies on specific questions, research agendas will be driven by the development of new sources and more powerful means of assembling, managing and sharing of data. Surrounding all are persistent calls for closer scrutiny of the scientific basis of regulatory decisions, the determination of causality, and the eventual outcomes of adopted measures. The following sections briefly outline some of the areas likely to be important over the next several years.

Continuing Questions About Ambient Air Quality Goals – Decisions Amid Both Increased Evidence and Further Uncertainties

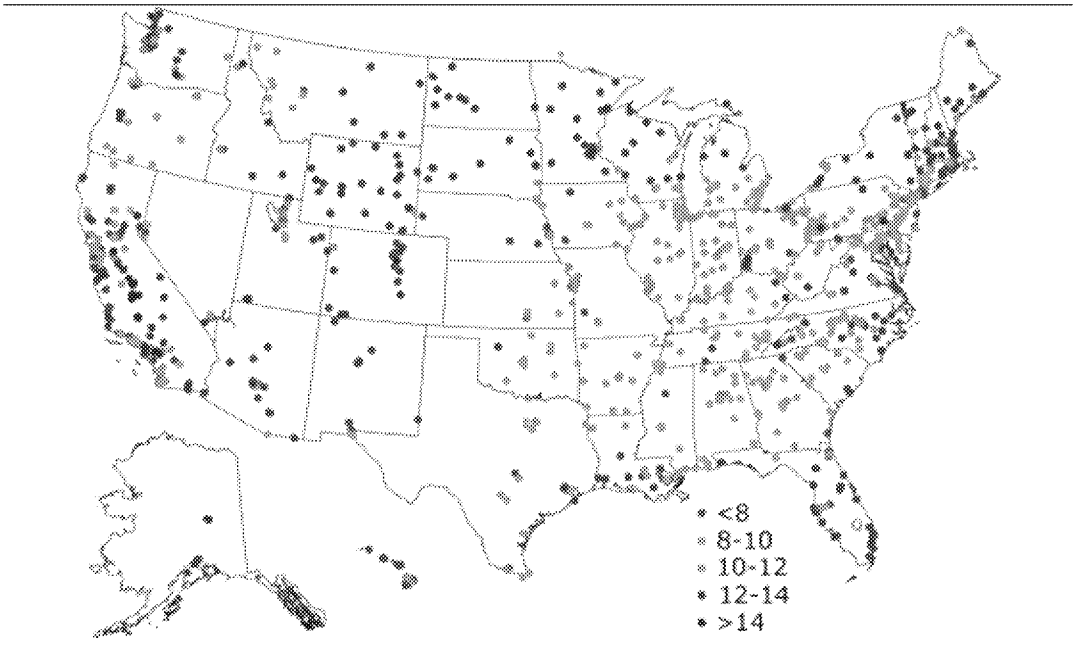
The review of the latest science on particulate matter ($PM_{2.5}$), ozone, nitrogen dioxide (NO_2) and other pollutants – and the consideration of current and future ambient air quality standards - is continuing at a sustained pace in the US, Europe, and globally. Specifically:

- In the ***United States***, the U.S. Environmental Protection Agency has recently completed the review of the U.S. National Ambient Air Quality Standards (NAAQS) for NO_2 and is deep into the review of the science for the NAAQS for $PM_{2.5}$ and ozone. These latter have a nominal target for completion by the end of 2020, with implementation to follow throughout the 2020s.
- At the ***World Health Organization,*** the review of the Worldwide Air Quality Guidelines is proceeding forward with the planned completion and journal publication of systematic literature reviews for the major pollutants, i.e. $PM_{2.5}$, ozone, NO_2, CO, and some air toxics, to be published in 2019 – and the completed reviews and establishment of guidelines likely to take place in the 2021 time frame. While these guidelines do not directly affect US standard-setting, they do play a significant role in the setting of European Limit Values as well as standards set in many countries around the world (e.g. China has set their $PM_{2.5}$ standard at a level (35 $\mu g/m^3$) equivalent to the highest tier of the WHO Air Quality Guidelines) and are of great interest to US and global industry.
- The ***European Union*** is currently conducting a *Fitness Check* review of its entire Limit Values setting and implementation program. That process – with extensive stakeholder input – is expected to be completed later in 2019. Following that — and pending the establishment of a new European Commission and election of a new European Parliament — the European Commission is expected to consider re-visiting the current Limit Values for $PM_{2.5}$, NO_2, and others.

- There is growing awareness of air pollution issues in many of the world's rapidly developing economies:
    - ***China*** has escalated the pace and extent of the country's efforts to improve air quality. A series of stringent emission control measures have resulted in the first documented significant reductions in ambient levels. Those levels, however, are still well above the China $PM_{2.5}$ air quality standard; further work will be necessary and has been initiated.
    - In India, growing awareness of the problem has led to accelerated implementation of new standards for vehicles by 2020, expanded use of LPG for household fuel, and the launch of the first-ever National Clean Air Programme (NCAP). Significant implementation efforts are now being discussed.
    - In both countries and around the developing world there is a need for high-quality local science – especially on longer term effects - to inform the needed, continuing and challenging air quality decisions.

The current NAAQS and WHO assessments highlight a number of uncertainties and limitations in understanding that are likely to be key areas for future reviews. Some reflect longstanding questions while others have arisen with more recent concerns.

- With levels of PM declining across the US (Figure 3) the question of whether a threshold level of effects from PM exposures exists or can be determined through epidemiological analysis is a persistent challenge that may gain new attention as studies reporting associations at very low levels of ambient concentrations are published.



Source Permission pending: U.S. EPA 2016 analysis of Air Quality System network data 2013–2015.

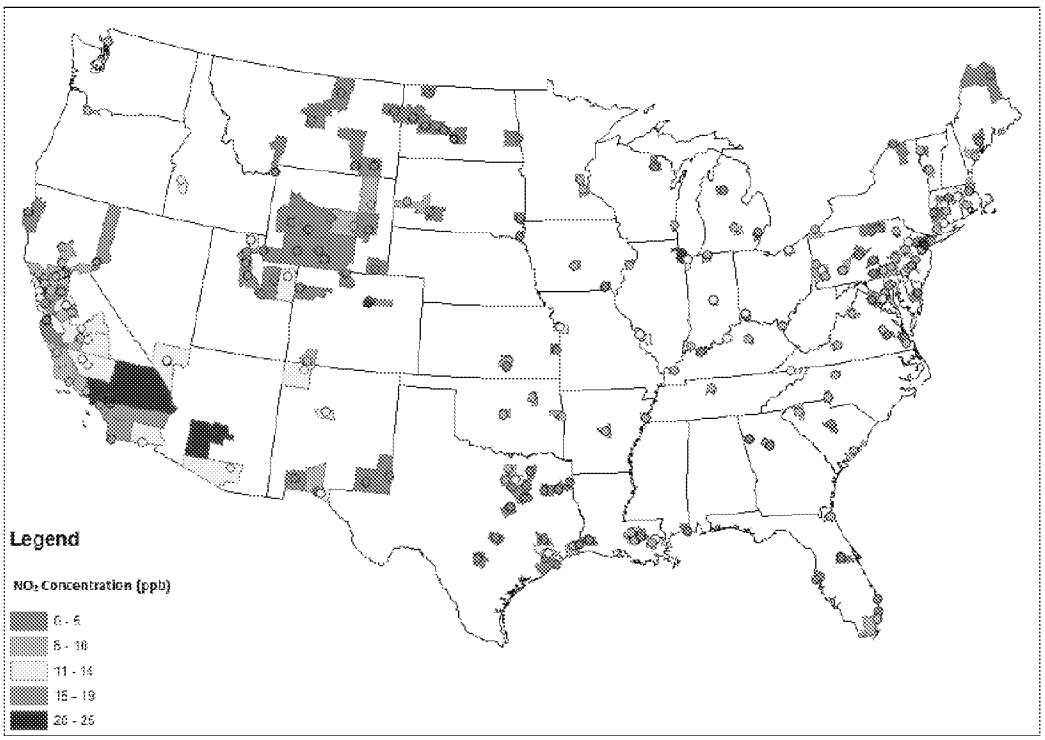
Three-year average $PM_{2.5}$ concentrations 2013–2015.

Figure 3 U.S.EPA Draft PM ISA OCTOBER 2018

- At the same time, the advent of these questions and publications about low-level associations has also raised renewed questions about how to best determine the causal connections

between exposures and effects, especially regarding other lines of evidence – from animal toxicology and human clinical studies – which are more difficult to conduct at such low levels. The current debates have also amplified the need for and implications of *Accountability* studies designed to test whether actions taken to reduce air pollution have actually reduced exposure and had health benefits.

- There has also been growing attention to exposures to and health effects from NO_2 with somewhat different patterns of regulatory and policy activity on both sides of the Atlantic.
  - In the US, following an earlier review of the NAAQS for NO_2, a new network of roadside monitors was installed to monitor both NO_2 and $PM_{2.5}$. However, the relatively low levels of NO_2 found has led to a scaling back of those monitors for NO_2 and a decision to retain the current NAAQS, even while retaining the roadside monitors for $PM_{2.5}$. (see Figure 4)



Note: NO_2 = nitrogen dioxide. Concentrations indicated are the highest concentration in the county and do not represent countywide concentrations.

Source: U.S. Environmental Protection Agency 2014 analysis of data from state and local air monitoring stations.

U.S. annual average nitrogen dioxide concentrations for 2013.

Figure 4 U.S. EPA NO_2 ISA Final 2016

  - In contrast, in Europe, the higher levels of NO_2 at roadside (due in part to the higher proportion of earlier model, less well controlled, light duty diesel vehicles) – and a significantly more stringent Limit Value than the US NAAQS – have resulted in many more locations facing a challenge of reducing NO_2 levels and exposure. (see Figure 5)

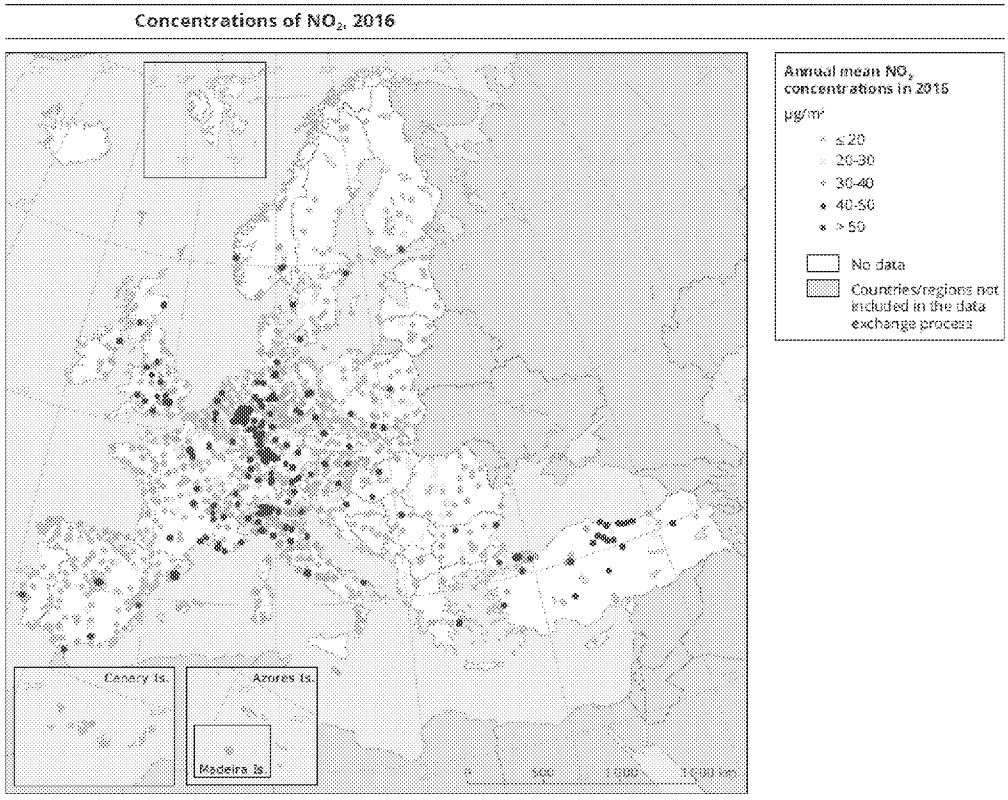


Figure 5 European Environment Agency Air Quality in Europe 2018

Source Emissions – Transport and Energy Choices

Interest in mobile source air pollution emissions has continued to grow around the world and will likely continue to expand over the coming years as vehicle ownership and miles traveled (VMT) grow, and despite significant achievements in reducing in vehicle emissions. At the same time new, potentially disruptive mobility technologies – electric and autonomous vehicles, and car sharing -- are likely to begin to change the very nature of vehicle fleets and emissions. However, despite the significant progress in these new technologies, it is likely that the great majority of light duty vehicles to be introduced over the next decade will continue to be enhanced efficiency internal combustion engines, primarily employing gasoline direct injection engines.

The continued growth vehicle ownership and VMTs has led to continued attention to vehicle emissions standards in major markets around the world, including the implementation of Bharat Stage VI/6 standards in India, China VI/6, potential new additional NOx controls in California and the US for heavy duty vehicles, and the initial discussions about a new EURO VII/7 in the coming decade. This newer wave of regulation is attempting to address a range of issues:

- Continued air quality concerns, particularly around ozone and the role of vehicle NOx emissions in the persistence of continued high ozone levels in some regions. This has been the case in California, where the challenges of ozone attainment are seen as demanding significant new actions, in part to address concerns that diesel emission control technologies may not yield the

expected NOx reductions from the 2010 rules; action which US EPA has expressed interest in beginning as well for other regions.

- Highly visible cases in both Europe and the US of problems with actual in-use emissions far exceeding standards are leading to far-reaching effort to control real driving emissions (RDE) in Europe and to strengthen in-use enforcement in the US.
- Rapid transitions in engine technologies and fuels, pursued for fuel efficiency or other goals, directly bear on emission control considerations in various ways. Some emerging technologies have raised questions about changes in the composition and pattern of emissions, especially in the potential for increased ultrafine particle emissions. These concerns played a role in the development of a particle number standard for both diesel and gasoline vehicles in Europe, and continue to be raised elsewhere in a number of policy and regulatory discussions.
- Continuing and growing focus on reducing emissions from existing fleets, including funding of retrofit and replacement of 'high-emitters,' and the new US roadside monitors (see Figure 6) which are likely to focus increased attention on PM exposures, even as NO_2 exposures have been found to be lower than expected.
- With the availability of low-cost sensors, the availability of widespread information on air concentrations – though of uncertain quality – is like to result in increasing pressure to control such community and neighborhood emission.

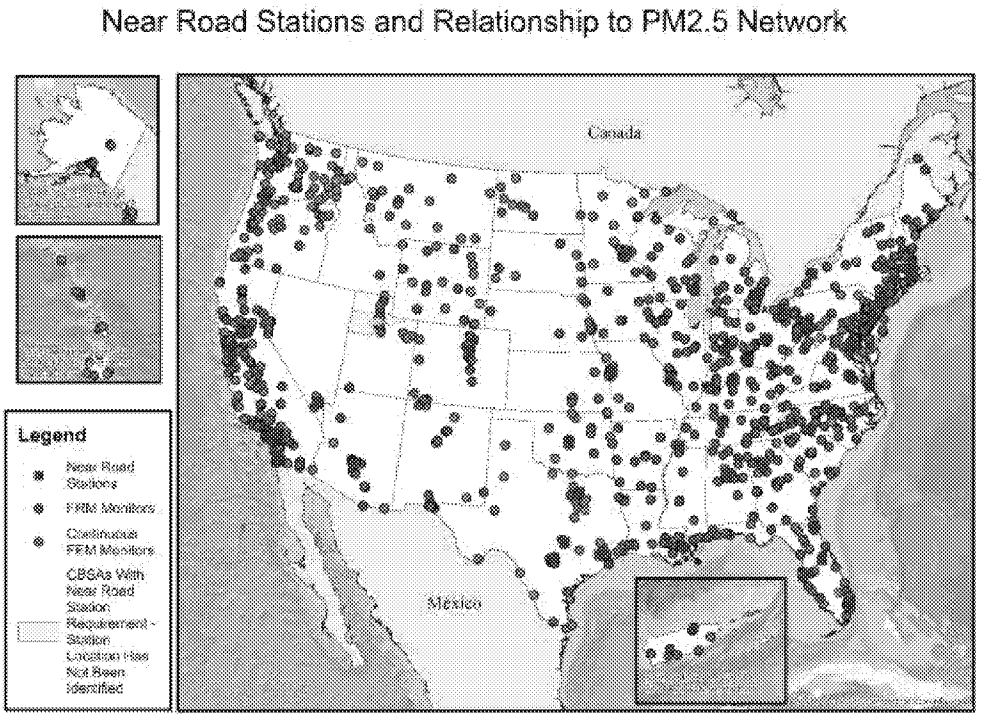


Figure 6. U.S. EPA Draft PM ISA October 2018

An Emphasis on Regulatory Effectiveness and Transparency

With the advent of increasingly stringent rules at lower levels of air pollution, there has been growing attention to the effectiveness of regulations, transparency of rulemaking, and the

ownership and control of the data underpinning scientific research in ways that are particularly relevant for air pollution decision-making.

- A key goal involves demonstrating the benefits that accrue from efforts to reduce emissions. The need to hold regulations accountable, i.e. to better understand and measure the outcomes of air quality interventions, continues to be a high priority among policy makers, who seek both a better grasp of the costs relative to the benefits of risk management decisions and a more robust way of evaluating the likely impact of alternative approaches. However, the direct demonstration of such benefits remains challenging in many situations because of the overlapping nature of regulatory program implementation and concurrent, unrelated changes – such as in the economy, employment, and health care – which also affect health.
- Equally important are longstanding debates over how to best ensure that the scientific evidence relied on in regulatory processes is properly developed and interpreted in the most *transparent* manner possible. The challenge of satisfying demands for greater transparency while meeting other imperatives heightens the value of sound models of reanalyzing and evaluating data.
- These issues also apply increasingly to enhancing the transparency and quality of any *systematic review* of scientific literature, including establishing a priori protocols, identifying the tools to be applied to find publications, and to evaluate them for quality and risk-of-bias.
- *Facilitating public access* to federally-funded research was established as an administration policy objective in 2013 and Federal agencies have been engaged in a coordinated effort to develop and implement access plans. While the scope of concerns is wide and touches on fundamental aspects of the scientific enterprise, questions such as how to best enable innovative approaches to previously unexploited sources of information, from often dispersed and enormous datasets collected for disparate purposes, directly bear on how future air pollution health research will be designed and practiced.

SCIENCE CHALLENGES

Finding the best scientific approaches to assessing exposures and health effects of air pollutants continues to pose significant challenges. The following are the highlights of some such challenges; in the "Major Research Opportunities" below, we discuss how HEI plans to approach them.

- *Effects of exposure to low levels of pollutants*: as we discuss above, evidence is emerging that even at and below the ambient NAAQS standards for PM and ozone, adverse health effects are observed. If these observations are confirmed by additional, well-designed analyses, they will be of great interest to scientists and policy makers alike. However, very large populations and quality exposure assessments are needed for such studies, and methods for ensuring the highest possible control for confounders in these large populations remain challenging.
    - Further, the advent of large population results poses *a challenge to animal toxicology and human clinical studies* where small numbers of subjects and high costs makes testing of low-level effects difficult.
- *Information on large populations*: Perhaps the best source of health data on large populations is from census and health care utilization organizations (health insurance companies or federal programs). However, access to and analyses of such data are complicated by confidentiality and privacy issues, many of which are ensured under federal and state policies.
- *Newly developing methods for testing and determining causality.* HEI and other science has been investing in developing and applying new statistical techniques – causal inference statistical

models – to attempt to enhance the determination of whether a particular exposure *causes* an effect. These models are still in early stages of development but offer a potentially valuable complement to traditional weight of evidence techniques.

- *Availability of reliable data on population exposure*: The reliance on central site monitoring data alone has well recognized limitations. Although there have been improvements in exposure modeling (e.g. land use regression) there now several emerging trends to attempt to improve exposure assessment. These include:
    - *Microscale exposure assessment*, in some cases taking advantage of new *low-cost sensors* to greatly expand intensive exposure measurement. These techniques can enhance coverage of and variability among within populations. They come however, with the challenge of ensuring the quality of such measurements. These sensors are also increasingly being used in *Citizen Science* resulting in greater democratization of accessibility of the data, but also with increased challenges of risk understanding and communication.
    - Increased reliance on *satellite imaging data* for estimating PM concentrations – and increasingly for other pollutants -- in order to maximize the populations and areas available for analysis, but this approach has not been fully evaluated and questions about exposure measurement errors persist.
- *The challenge and opportunity of "big data":* In analyzing both the health status and exposure of large populations using innovative new methods – including some employing uncommon approaches such as "citizen science" and exploitation of larger data bases becoming available through large-scale networked populations (i.e. so-called "big data") – may offer opportunities to analyze exposure and effects with much greater refinement, although many conceptual and analytical issues need to be addressed to ensure that the results can be seen as valid.
- *Methods for assessing the toxicity of ambient air pollutants*: Although numerous methods to assess processes, such as genotoxicity, oxidative stress, mitochondrial damage, etc., are being used, their protocols have not been standardized, making it difficult to compare studies from different laboratories. There is also a recent trend in applying methods developed by molecular biologists – such as genomics, proteomics, and other "-omics" – to environmental health problems. Although several groups are applying these new methods, there is a need to develop these methods further, to standardize their protocols, and to assess their ability to predict effects in humans.

THE MAJOR RESEARCH OPPORTUNITIES

HEI envisions working on the following four main areas of research:

- Accountability: Testing the Links Between Air Quality and Health
- Complex Questions for the Complex Air Pollution Mixture
- Transportation and Urban Health
- Global Health

Accountability: Testing the Links Between Air Quality Actions and Health

HEI has a longstanding commitment to accountability research. Accountability studies evaluate the effectiveness of environmental regulations, providing a critical feedback loop to decision makers.

HEI's interest and commitment to accountability studies stems in large measure from the importance of assessing whether complex regulations and other interventions are actually yielding the improvements in air pollution and public health that were initially projected. Given that air quality has improved over the past decades, further improvements become more difficult to achieve and more costly. Early on, HEI defined initial concepts and methods with the publication of a major Monograph. Since then, HEI has funded two successful waves of studies that evaluated both local interventions occurring over relatively short periods of time as well as more complex, longer-term interventions at the regional or national level. Lessons learned about regulatory efficacy from these studies can inform the design and implementation of future efforts to improve air quality.

Currently, HEI has embarked on a third wave of studies that are expected to start in late 2019. RFA 18-1 solicited studies in the following areas: (1) Long-term complex regulatory programs: studies that evaluate regulatory and other actions at the national or regional level implemented over multiple years; (2) Interventions at the local level: studies that evaluate actions targeted at improving air quality in urban areas, with well-documented air quality problems and programs to address them, including but not limited to low emission zones, congestion charging, and so-called diesel bans; (3) Ports and global transport: studies that evaluate regulatory and other actions to improve air quality around major ports (both marine and air) and transportation hubs and corridors; and (4) Methods development and dissemination: studies that develop, apply and disseminate statistical and other methodology for conducting such research.

Looking ahead to the 2020-2025 Strategic Plan, HEI plans to continue its leadership role in this area:

New Accountability Research

HEI will strengthen its leadership in conducting Accountability studies of the ***air quality and health impacts of air quality interventions.*** After completing 13 seminal studies during the last decade, a new program of research – with studies funded under RFA 18-1 (see above) to be launched in late 2019 – will set the stage for the next generation of accountability research during the core years of HEI's new *Strategic Plan 2020 - 2025.* Such studies are a key underpinning of smart policy and regulation. They provide one of the few avenues for rigorously testing the links between emissions, exposure, and health. In addition to evaluating effectiveness of air quality regulatory actions, this program also aims to develop more robust research designs and statistical methods for estimating the health effects of air quality interventions.

New Methods:

HEI continues to foster development of new statistical methods to enable direct evaluation of well-defined, long-term regulatory interventions, for example by using national databases such as Medicare or census data or large cohorts. Because the effect on health of further reductions in air pollution are likely to be small, particularly in high income countries with low ambient levels, it is important to develop a sophisticated perspective on whether future studies will have the power to detect and quantify an effect — if there is one — and to describe a null effect with enough precision to be informative for policy purposes. It will be critical to pay serious attention to the sensitivity of statistical inference to model specification and time-varying confounding or implement quantitative bias analyses. Where possible, HEI is asking researchers to evaluate whether their study can add to the evidence base for a causal relationship between air pollution and health.

Specific Study Areas:

- National- or regional-scale air quality actions over the long term. In the US there have been on-road and off-road diesel rules, rules covering locomotives and marine vessels, standards for utilities and industrial boilers, and interstate rules. Similar efforts are taking place in Europe and Asia.
- Air quality actions at the local (urban) scale. Recently, many cities have started to implement actions to improve air quality, e.g. congestion charging and low emission zones, limiting driving days for cars with certain license plate numbers, implementing road closures or restricted access of certain streets (e.g. Oxford Street in London), or outright bans of certain vehicles, for example diesel vehicles, mainly in Europe. These actions go hand in hand with efforts to transform urban mobility. Those new developments lead to growing attention on the fuller range of potential effects of transportation and mobility decisions on public health, including the positive effects of an increase in physical activity.
- Regulatory actions targeted at major ports and transportation corridors. Over the past decade, several states have started to develop complex programs to reduce emissions from "goods movement," by targeting marine vessels, harbor craft, railway locomotives, heavy-duty trucks, and cargo handling equipment that contribute to concentrations of particulate matter and nitrogen oxides, mostly from diesel engines. In addition, ports are often situated adjacent to densely populated areas, with a relatively high percentage of disadvantaged populations. Internationally, efforts have been made to reduce emissions from ocean freight in Emission Control Areas designated by the International Maritime Organization (IMO) to reduce air pollution emissions from ships that affect ports and coastal communities. Similar issues apply to airports, where there is a need for information on ultrafine particles and noise and effectiveness of measures to reduce their impact.
- *Environmental Justice:* Where possible, HEI asks researchers to focus on sensitive populations (e.g. children) who may be disproportionally affected, and on communities that may be at greater risk due to ethnicity, socioeconomic status, proximity to roadways and stationary sources, and the cumulative effects of multiple pollutants.
- And other relevant areas identified by investigators and stakeholders.

Complex Questions for the Air Pollution Mixture

Levels of ambient air pollution have generally declined over several decades in North America, Western Europe, and other high-income regions, due in large part to air quality regulation and technological improvements. The levels of many ambient pollutants today are 60 percent or more

lower than the levels 25-30 years, and concentrations of hazardous air pollutants have seen even steeper declines, sometimes by as much as two orders of magnitude, over the decades. Yet, air pollution problems continue to be of public health significance and interest remains very high among the policy and research communities for a better understanding of exposures and health effects. In this context, the following factors are noteworthy:

- An association between exposures to low levels of air pollution – even below the current standards – and health effects is being reported in several new epidemiological studies, including early papers from two studies being funded by HEI. Using sophisticated new techniques for exposure assessment at very large scales and health databases containing tens of millions of records, as well as developing new methods for meticulous statistical analyses, these findings raise questions about the level of protection offered by the current standards, at least for $PM_{2.5}$, and probably for ozone and NO_2 as well.

- HEI's NPACT studies – a systematic, multidisciplinary program that used coordinated toxicology, epidemiology and exposure assessment research to examine and compare the toxicity of PM components, and found that none of the particle components could be definitely excluded as having health effects, thus supporting the current regulatory approach of targeting the entire PM mix. Yet, given the varied approaches that can be, and are, used to control emissions from different sources, interest remains high in source contribution (and composition) to toxicity of PM. Interest also remains very high in other characteristics of PM, particularly size.

- Air pollution sensors that are less expensive than traditional regulatory- or research-grade monitors offer the promise of improving exposure assessment of outdoor air pollution. Given their lower cost, such sensors are being widely used by individuals and deployed by community and other organizations to learn about their local or individual exposures. Two main concerns here are first, obtaining data of sufficient quality is hampered by the rapidly changing nature of the technology and the fact that the influence of temperature, humidity, and other conditions becomes important when sensors are deployed in environments that are not climate-controlled and are used for extended periods of time. And second, information on the risks of air pollution is based on population-level studies, and it is very difficult to translate exposure information to local or individual risks.

These and similar challenges point to the need for carefully crafted and well thought through research programs to address them, and present opportunities for HEI to design research and review activities to answer them.

Health Impact of Exposure to Low Levels of Air Pollutants:

- HEI will complete, within the first years of the new Plan, its health effect studies of low-level exposure, applying innovative exposure and analysis techniques, examining PM, ozone, and NO_2 effects at low ambient levels, in the United States, Canada and Europe. HEI's path breaking program of these major studies in millions of participants will produce important new findings that will inform EPA decisions on National Ambient Air Quality Standards (NAAQS) and WHO decisions on Global Air Quality Guidelines, as well as future estimates of benefits from air pollution reductions. These studies will also pave the way for novel methodologic advances in air pollution studies for years to come.

These unprecedented efforts to gather comprehensive information on tens of millions of participants and their exposure will provide opportunities to apply the same or similar methods for exposure assessment for comparison among the different studies, best ways to address confounders and measurement error, and other analytical approaches, including methods for causality inference. Additional questions that may be pursued include multi-pollutant analyses methods and PM composition or source analyses, methods developed for one cohort and tested in another, sources of variability in effects in the various populations such as age structure, SES position, and access to medical care, to name just a few.

Studies on the Mechanisms of Health Effects of Low Level, Chronic Exposure

- The observation of associated health effects in early epidemiology analyses in low exposure studies raise questions of the biological/toxicological mechanisms that may operate under chronic, low exposure conditions. Though toxicological and mechanistic confirmation of effects is not essential for reliability of epidemiologic observations, such consistency of evidence is strong, supportive evidence for plausibility (and can even contribute to causality). How might these questions be addressed? HEI could, through workshops and exploratory studies, investigate the best ways to research these mechanistic questions and is eager to hear comments and ideas on promising directions that HEI might pursue.

- Another area with a need for research on the mechanisms of chronic exposures at low levels relates to the health effects of ozone where epidemiological studies have shown associations with cardiovascular mortality but where results of ozone exposure in chamber studies have generally – especially at low levels – not found effects. This may point to the need for new approaches to mechanistic studies, and application of novel methods. Here too, HEI would welcome comments and ideas on scientific activities that HEI might consider.

Characteristics and toxicity of PM

- There continues to be intense interest, and potential policy payback, regarding whether any specific characteristic of PM confer differential toxicity, which could lead to actionable control strategies. Embedded in this issue are questions regarding sources of PM (e.g., mobile vs stationary sources, and also biogenic sources, and chemical composition), size characteristics (e.g., ultrafine, and coarse particles, and features of size, such as diameter vs surface area, surface charge or other features), nature of PM (e.g., freshly emitted PM, SOAs, aged PM), and many others. Given that epidemiological studies on such questions are very difficult and past studies have not provided clear cut answers, should HEI take a renewed look at these questions? What approaches and developments in toxicology may be most useful for such applications?

Transport and Urban Health

There have been substantial improvements in vehicle emissions and transport-related air quality as requirements for cleaner fuels and technologies have been initiated and as transportation fleets are being replaced. These are having overall benefits even as the numbers of vehicles and travel activity grows. However, three factors contribute to continued attention to the role of transport in health:

- The growth in traffic activity around the world, and the persistence of older, less well-controlled vehicles in the fleet, have continued to focus both citizen and policy attention on potential traffic air pollution exposures. This has been amplified by recent awareness of the significant in-use exceedances of emission standards by many vehicles, especially in Europe. The past decade has also seen increased roadside monitoring of air pollution levels.
- While the enhanced regulations and other activity worldwide to reduce vehicle greenhouse gas emissions is proceeding - resulting in substantial increases in the development and introduction of new "zero emission" technologies such as electric vehicles - the great majority of vehicles being introduced over the next decade in response to these regulations are expected to continue to be internal combustion engines. These engines - primarily gasoline direct injection (GDI) - are substantially cleaner than older engines, but do, unless further controlled, have the potential for higher particle emissions than spark-ignition engines.
- Increasingly, recognizing the many urban factors that may contribute to population health, the evaluation of potential effects of traffic exposure has been broadened to examine a number of other factors that may also affect health, including noise, socioeconomic status, and access to green space.

At the same time, urban transport is going through potentially major and disruptive changes. A host of new mobility technologies (e.g. electric and autonomous vehicles) and transport services (e.g. transportation network companies such as Uber and Lyft) are being developed and implemented in cities in North America, Europe, and around the world. The exact trajectory of these changes is hard to predict, but depending on how the changes evolve, these could result in substantially reduced traffic congestion and air pollution, or potentially increases (as we have seen recently with the initial implementation of the TNCs resulting in increased vehicle travel).

These trends increase the need for targeted, advanced, and innovative exposure and health research to inform likely future questions on reducing such exposures and effects. They pose several major scientific challenges and opportunities for HEI to consider in constructing its *Strategic Plan 2020 – 2025*:

A First Step – the Updated HEI Traffic Review

Under the current Strategic Plan, HEI's new Expert Panel on the potential health effects of exposure to traffic is actively engaged in reviewing the literature published since HEI's earlier review in 2010. Since that time, over 1,000 studies of traffic exposure and health have been published. The new Panel is systematically screening and evaluating these studies, with an emphasis on studies of long-term effects. This effort, which is expected to be completed around the end of the first year of the new Strategic Plan will enable a detailed review of whether some of the challenges identified in the 2010 report – such as the paucity of studies with high quality measurements of traffic exposure – have been addressed. The Panel is endeavoring – in the face of this substantial number of new studies - to update our understanding of what we know about a variety of widely studied health effects and their potential relationship to traffic exposure. Importantly for HEI's *Strategic Plan 2020 – 2025,* this new review should also – much as its predecessor did – set the stage for the highest priority further studies to be tackled under HEI's new Plan.

Placing Transport Effects in Context of the Broader Range of Urban Health Factors

The HEI *Strategic Plan 2020 – 2025* will provide an opportunity to learn from HEI's newest studies of traffic, which were designed and implemented in the wake of a series of HEI studies to enhance the assessment of traffic exposure for use in epidemiologic studies (a key recommendation of HEI's earlier traffic review). These new studies, underway currently and likely to be reviewed and

published near the middle of the new Strategic Plan, are incorporating improved traffic exposure approaches but also, importantly, considering other key factors found in the urban traffic environment that may also influence health. These factors include noise, socioeconomic status, and access to green space, for which there are separate literatures suggesting potential effects, that may modify or confound the effects of traffic air pollution exposure, and examining them all together should enhance our understanding of their roles in urban health.

At risk Populations

A not insignificant part of the interest in recent enhanced monitoring of roadside air pollution exposures is the disproportionate representation in roadside populations of environmental justice communities, i.e. populations of lower socioeconomic status and often peoples of color who may have inadequate medical care and/or other underlying health challenges which may raise their sensitivity to the health effects of air pollution. Also potentially of concern are populations in these settings with certain underlying diseases that can increase sensitivity to the exposures (e.g. asthmatic children and adults, and those with diabetes). In addition to the three new studies above of traffic exposure, socioeconomic status, and other factors, HEI is supporting an additional study in New York (by **Jane Clougherty**) exploring these issues of disproportionate exposure and effects and a separate microscale assessment of traffic exposures in urban settings (by **Josh Apte**). Should the early findings of this group of studies support it, HEI would, in a new Plan, enhance its efforts to probe this important set of questions.

Exposure Components of Special Interest

While traffic emissions have been dropping over the past several decades, some components of the traffic exposure mixture continue to call for and merit attention. They include:

- *Ultrafine particles:* HEI's 2013 Perspectives *Understanding the Health Effects of Ambient Ultrafine Particles* summarized current science on exposure to and health effects of ultrafine particles, and concluded "The current evidence does not support a conclusion that exposures to UFPs alone can account in substantial ways for the adverse effects that have been associated with other ambient pollutants such as $PM_{2.5}$." A recent review conducted for the German Umweltbundesamt (the German EPA) reached similar conclusions. These reviews also identified a number of continuing research needs – and questions continue to be raised about ultrafines potential role in effects observed in traffic exposure studies, especially because it seems likely that some new technologies being introduced in the market, such as gasoline direct injection (GDI), emit UFPs. This set of issues is likely to continue to be of importance as decision makers in the US and globally consider what if any action to take on particle number standards for light duty and heavy-duty vehicles in light of the European action in this area. HEI is inviting new exposure studies to better characterize long term exposures to harder to assess air pollution components such as ultrafines (RFA 19-1); we would welcome input on this draft plan on the priority of further research in this area, and which areas should draw the greatest attention.
- *Non-tailpipe Emissions:* With a significant reduction of tailpipe PM emissions from gasoline and diesel vehicles, interest in non-tailpipe emissions of motor vehicles is increasing, and there is interest in understanding how the non-tailpipe emissions could affect exposures of individuals living near major roads. Since relatively little work has been done on such emissions, HEI has initiated some research to characterize these exposures and their potential effects. Understanding these exposures is not, however, always straightforward and continued attention to improving exposure assessment is needed. HEI would also welcome input on the priority for, and directions in, this research area under the new Plan

- *Increased use of Low Carbon and Biofuels*: As one element of a transition to lower vehicle greenhouse gas emissions, efforts to increase use of low carbon fuels are continuing. While these fuels offer an opportunity for cleaner emissions, they may also introduce new chemical compounds into the fuel mixture and combustion process, with a wide variety of potential effects on emissions. HEI has continued to track these questions over the current Strategic Plan, with a major multi-party expert workshop convened in Chicago in 2016 and monitoring of the latest science. Given HEI's longstanding attention to the implications for air quality and health of changing fuels and technologies, HEI will be carefully assessing these developments and identifying constructive ways that HEI experts could inform future decisions about these fuels.

All of these components of the traffic mixture continue to attract scientific and policy attention. HEI plans to continue to work with its Committees, sponsor experts, and other stakeholders to track technical developments, and identify the highest priority questions for HEI to address through targeted workshops and, if the questions merit it, new research.

Global Health

HEI, through its core air pollution and health program, has long provided domestically and globally relevant science designed to inform decisions by EPA and industry sponsors, WHO, the EU and others affecting public health, technology and potential regulation. This science also helps inform regulatory decisions in developed countries that are then transferred to the developing world (e.g. EURO vehicle standards)

HEI's future work in developing Asia and beyond, with supplemental support, will enable HEI to provide much needed credible science to inform decisions in parts of the world with some of the very highest levels of air pollution on the planet. To do this HEI will work in partnership with leading global research institutes and investigator teams employing cutting edge satellite data, multi-scale atmospheric models, ground-based monitoring, and the growing base of health studies in many countries, often in a capacity building relationship with local scientists. This approach, and HEI's careful communication to decisionmakers builds trust and provides unique traction for results that fosters the reliance on high quality consistent science for local decisions.

Europe and the Developed World

In Europe and elsewhere in the developed world HEI's engagement reflects the established priorities laid out in the body of this draft Strategic Plan; this will result in the provision of targeted science relevant to the needs of core sponsors, including vehicle manufacturers and regulators alike, as well as WHO, DG Environment, national governments and other key European institutions

Among key areas of wide interest to continue to be pursued in Europe as part of HEI's broader global efforts are:

- Studies of major pollutants ($PM_{2.5}$, ozone, NO_2, CO, and some air toxics)
- Studies of low-level effects of air pollution
- The health impacts of exposure to traffic related air pollution
- Studies of ultrafine particles and advanced technology internal combustion engines

This and related research will help inform consideration of European limit values, emission ceilings, vehicles and other emission standards, and national and city level decisions about traffic control and related interventions. In turn, these decisions will provide guidance to many countries in the developing world.

Developed Asia and Beyond

In developing Asia and beyond, as reported in SoGA 2019, air pollution and associated mortality and morbidity continue to increase in many areas, with over 90 % of the world's population living in regions that exceed the WHO's most stringent health-based guideline. At the same time, as reported in GBD-MAPS, accelerating economic development will result in a number of changes that can act to increase emissions, including increases in vehicle ownership and miles traveled, electrification and industrial activity. While growth will bring many benefits in improved socio-economic status, and declines in solid fuel use, developing nations will be hard pressed to reduce air pollution and associated CO_2 emissions in the near term. In this context understanding the health impacts of key sources will be critical to help guide health relevant interventions in nations with limited resources.

To respond to these and other challenges HEI proposes, with continued supplemental funding, to focus on several key areas:

Global Burden of Disease: HEI will continue to work with IHME, providing leadership on the air pollution working group to update both health and monitoring data, refine methods to estimate exposure response, and evaluate additional health endpoints and pollutants for inclusion in GBD 2019 and beyond

GBD-MAPS Global: Identification of contributing sources and their relative health impact is important to address air quality management at the national and sub national level. HEI proposes to build on its earlier GBD MAPS China and India studies by using global emissions inventories by country and sector combined with advanced modeling and updated integrated exposure response functions to build GBD-MAPS Global, a report on source-specific air pollution health impacts for all countries in the world. As in Asia, this data is expected to aid health-based air quality management in countries with limited ability to acquire this information, and when combined, provide a comprehensive global analysis of key sources, effects and trends. This will also enable, over time, the projection and tracking of changing sources as economies grow and evolve, e.g. shifts in main power sources, and expected growth in vehicle fleets.

State of Global Air: HEI will maintain and enhance its annual State of Global Air Report and database. This will enable continued identification and tracking of key progress and trends in global air pollution, beginning in 1990 through the current year, assessing levels of $PM_{2.5}$, and ozone, and the health impacts of ambient and household air pollution, including measures of life expectancy on global health. It will also provide an accessible and transparent mechanism for tracking progress in improving air quality.

New Research in a Capacity Building Framework: While there is a rich global literature on the health impacts of air pollution, there is growing recognition that a subset of key studies are needed in developing nations to credibly inform extrapolation to this body of existing science to national conditions. In addition, there is a dearth of studies of chronic exposures in Asian populations that would be informative in refining estimates of health impacts in these same populations. Under its new Plan, HEI plans to complete, peer review and publish the Asian cohort studies being undertaken by Vermeulen et al and, with supplemental support, HEI will identify and report on key gaps in the air pollution literature in developing Asia and seek to support studies to fill those gaps, pursuing a capacity building model designed to enhance both the skills of local scientists to conduct such research in the future and produce results with maximum credibility to local officials.

Cross-Cutting Issues

In reviewing these detailed major opportunities that HEI might address going forward, a number of specific health effects questions were identified that would not by themselves be programs of research in the new Strategic Plan, but which should be viewed as *cross-cutting issues* that should be integrated into all of HEI's work. Several issues were included in the Strategic Plan 2010-2015 but remain pertinent for future research:

Transparency in Policy-Relevant Science

Many practices and other aspects of generating scientific information, particularly for its usefulness for policy making, have come under close scrutiny in the recent past. There are several elements in this complex debate. First, environmental policies are health-based and there have been long-standing debates about replicability and reproducibility of the studies underpinning regulations (including data access, quality, and analyses); additionally, reproducibility of the broader scientific literature is the focus of recent debates in scientific journals and also is reflected in the US government's attention to transparency. Second, the methods and procedures, and the potential for introduction of biases in the drawing of inference from the scientific literature – in some cases, very vast literature – has been a subject of concern. Several guidelines and protocols have recently been developed, although their application has varied, partially due to the inherent features of observational epidemiology studies. Finally, recent years have also witnessed a growing interest in the application of statistical modeling methods to systematically explore causal relationships between air pollution and health; a variety of different methods have been developed, but the field is evolving and there are differing perspectives on how best to investigate causality.

HEI does not plan to engage in direct research or consensus building in these areas; however, these issues do intersect with HEI's research and review activities and we envision engaging in the following ways.

Data Access and Transparency are essential to the scientific process because they can provide insight into analytical and methodological details. Making data and analytical methods available allows others to replicate study results independently and, where necessary, perform alternative or additional analyses. As such, transparency provides equally valuable feedback to the decision-making process. Taken together, both accountability and transparency underscore HEI's commitment to improving science for regulations.

Throughout its history, HEI has had a commitment to transparency and data access and maintains a strong policy on facilitating access to underlying data and methods for the studies it funds. In the past, HEI has responded to requests from government, industry and others to reanalyze studies central to the regulatory process and evaluate their overall strengths and weaknesses, or their suitability for use in risk assessment. However, data for residential addresses and health outcomes in many cases cannot be made freely accessible to protect participants' privacy, limiting the ability to strictly replicate results.

During Strategic Plan 2020-2015, HEI plans to continue its involvement in this area, by making data from studies it funds widely available for reanalysis, replication, and extended analysis by others. Specifically, as discussed above under Accomplishments, HEI will work with the investigators of the low-level exposure and its other studies to make their data and codes available.

Systematic Synthesis of Information on Important Issues. Using special expert panels and its scientific committees, HEI has long played an important role in collecting, analyzing, and synthesizing scientific information on important issues facing the EPA and its private sector sponsors. This has taken the form of special reports and perspectives developed by special expert panels and staff. The most recent examples of such activities include a major review of the traffic

literature (2010), ultrafine particles (2013), diesel epidemiology studies among miners and truckers (2015) and new technology diesel engines (2017).

The process for performing and synthesizing reviews has been evolving and currently the use of *systematic* review protocols has been emphasized in the environmental health context. However, it is also becoming clear that such protocols – often derived from clinical trials literature – are not well suited for the observational epidemiology literature. The HEI panel reviewing the health effects from exposure to traffic related air pollution is currently working to adapt procedures for its review work. The Panel's protocol will be published in summer 2019 at the PROSPERO website (https://www.crd.york.ac.uk/prospero/), and the review using these procedures will be published early during the new Plan.

Analysis for Causality. HEI's work in this area is, by and large, integrated into other HEI research to develop statistical and analytical methods. In these areas HEI has played two key roles: to *develop innovative methods*, and then to *test and validate those methods* to ensure that they provide high-quality information for better understanding and decision making. Looking forward, there are several key opportunities for incorporating innovation and validation in all aspects of HEI's work, including

- *Testing Causality through Innovative Statistical Techniques* is a particular focus of research by Dr. Francesca Dominici and her colleagues under the low levels of exposure program. Specifically, Dr. Dominici is developing causal inference methods for spatio-temporal data that can be applied to the entire U.S., which is a highly complex endeavor. HEI may fund other efforts at causal modeling under its accountability program.
- *Other Enhanced statistical techniques:* In its new Plan, HEI will continue its 15+ years of success at identifying, developing, and validating innovative statistical techniques for analyzing the relation between air pollution and health. After funding several studies to develop novel statistical methods to address the multipollutant mixture in the past, there will be continuing opportunities to fine tune those and other methods and apply them to existing datasets and new research data alike.

Enhanced Exposure Assessment

A primary challenge in conducting health effects research is ensuring the highest quality assessment of exposure for the population being studied. To that end, HEI works to address exposure issues in every study it funds, and both the HEI Research and Review Committees include experts who work to oversee the exposure assessment in each study – and then to review it rigorously once the work is complete. Even as those individual studies take place, HEI is always looking for ways to improve the techniques for exposure assessment for application in future studies.

To that end HEI has some new activity just beginning under a new Strategic Plan, and is considering additional areas where HEI might engage during the course of the Plan:

- First, as discussed above, HEI has recently issued an RFA seeking to fund studies to advance exposure assessment for air pollution and health studies using sensors, mobile monitoring, tracking technologies, and other approaches. The studies would develop and apply novel approaches to improve long-term (months to years) exposure assessment of outdoor air pollutants whose levels vary greatly in space and time, such as UFPs, NO_2, and components of PM.

- Second, although HEI's current low-level studies are applying new satellite and chemical transport model techniques to estimate exposures, HEI will be closely following developments in this rapidly growing field and, as needed, identify specific efforts it might undertake to evaluate and enhance these techniques.

- Third, as noted under Transport and Health above, there are a number of components of the transport exposure mix which continue to attract attention for their potential shorter-term exposures and effects. HEI will continue to monitor these issues and identify roles that HEI might play in improving assessment of these exposures.

HEI would welcome comments and ideas on other exposure issues and research questions that HEI should be focusing on.

Sensitive and at-Risk Populations

Laws to improve air quality, in the US, Europe, and elsewhere, frequently call for protection of sensitive or susceptible populations. Based on previous health studies, it appears clear that certain groups in the population are, or may be, particularly sensitive to health effects of air pollution. Such groups include the fetus and children who are in active developmental stages; the elderly who may suffer from multiple illnesses; those with asthma, diabetes, obesity, cardiovascular, and other diseases whose underlying pathophysiology makes them more vulnerable; and those who are of lower SES and thus may face higher exposures and may have underlying health conditions. Also, in some situations, specific gene-environment interactions may confer susceptibility to individuals or groups. HEI will integrate such cross-cutting issues into its future research. More specifically, HEI may focus its projects on one or more susceptible groups or explore the role of genetic and epigenetic factors influencing health outcomes by utilizing techniques borrowed from genomics, proteomics, and other new biologic tools.

New methods for toxicity testing, mechanisms and biomarkers

HEI will also encourage in its research programs the use of new methods, model systems, and systems biologic approaches for toxicity testing, mechanisms and biomarkers, with the goal of improving exposure and dose-to-target tissue assessment, genetic or epigenetic factors affecting susceptibility, and species specificity. HEI is interested in studies focused on mechanisms of action, especially as they pertain to enhancing our understanding of species- or dose-related extrapolations or early markers of pathologic outcomes and may help identify biomarkers. Although many other groups at the EPA, National Institutes of Health, and elsewhere are developing such techniques, HEI will use its unique position to apply and test these techniques in challenging areas.

HEI sees several areas where the new methods may be particularly fruitful. First, in view of the increasing deployment of new fuels and technologies and the paucity of information about the health effects of their emissions, such methods will be particularly useful in the development of more reliable and cost-effective screening tools. Second, as discussed above, HEI is interested in exploring and potentially applying such new methods to study the effect of chronic exposure to low levels of air pollutants. Finally, although scientists have searched for biomarkers for a long time, advances in proteomics, genomics, systems biology, immunology, neurobiology, understanding of gene-environment interactions, and advances in various measurement methods raise anew the possibility that biomarkers may be found for certain pollutants, and these advances have the

promise of providing more reliable methods for dose or exposure assessment and early markers of disease. HEI will encourage the investigators it supports to propose such approaches in their research, ideally side by side with more traditional and well-validated approaches, to build a broader "tool box," for assessing exposure or health effects.

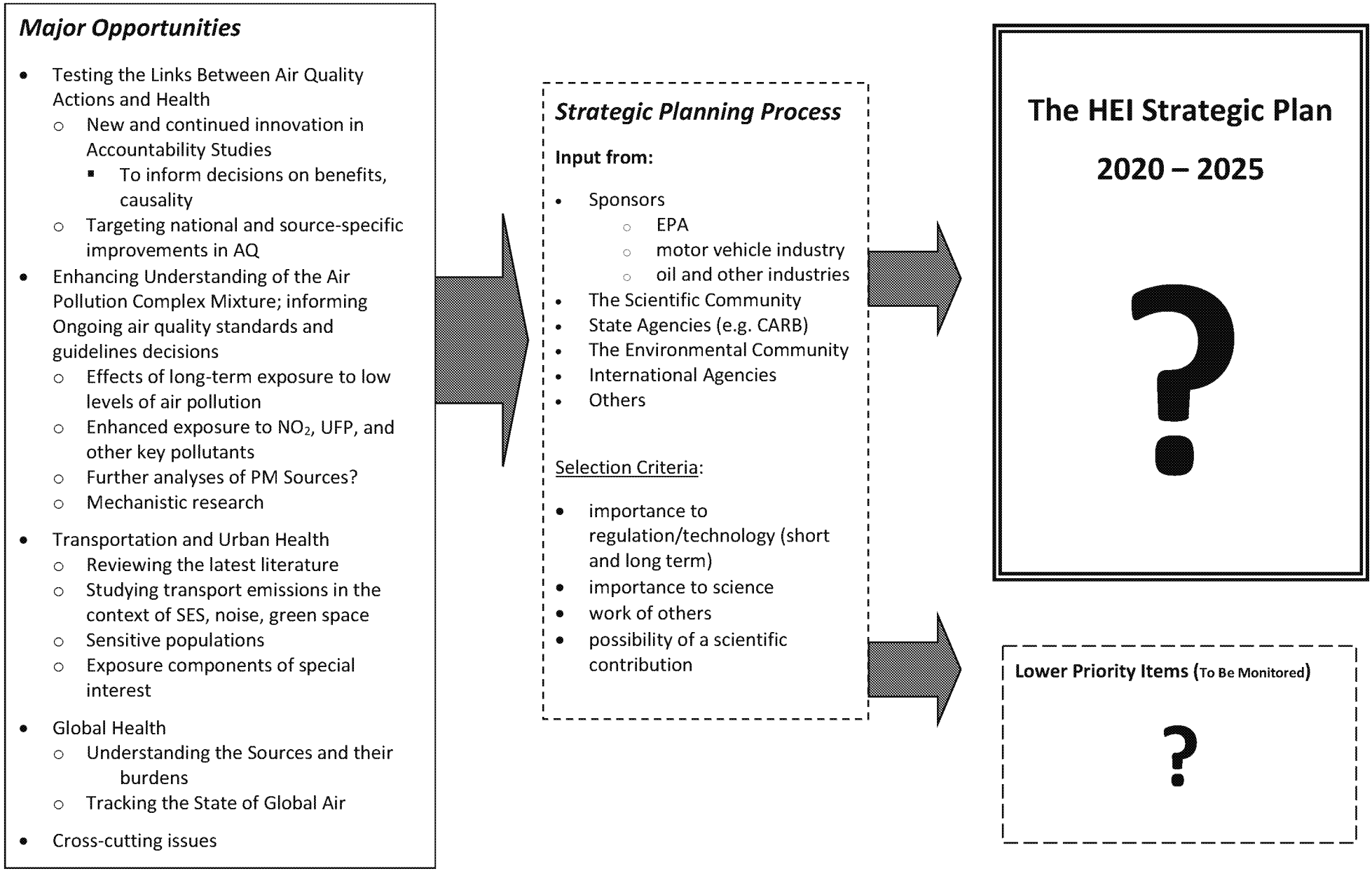
CHOOSING THE FUTURE

HEI has already begun to receive much valuable input from sponsors and others in putting forward the potential directions for the *HEI Strategic Plan 2020 – 2025* described above. As we go forward, and get comments on this draft of the Plan, HEI staff and committee members will address several criteria in selecting priority topics for the next five years. These include:

- the current state of knowledge about topics of potential interest,
- their importance for upcoming regulatory and technology decisions,
- how well they are being addressed by other organizations, and
- the likelihood that additional scientific work will produce useful findings at this time.

Figure 7 illustrates this process. In appraising how each of the possible directions addresses these criteria, HEI will also consider its ability to provide science to inform both near- and longer-term decisions, and the overall resources available to HEI to produce its science.

Figure 7. Choosing the Future



Message

From: Corey, Richard@ARB [richard.corey@arb.ca.gov]
Sent: 4/29/2019 11:14:19 PM
To: Grundler, Christopher [grundler.christopher@epa.gov]
Subject: RE: New Report Highlights Major Concerns With Trump GHG Vehicle Emissions Proposal

Thanks Chris.

From: Grundler, Christopher <grundler.christopher@epa.gov>
Sent: Monday, April 29, 2019 3:41 PM
To: Corey, Richard@ARB <richard.corey@arb.ca.gov>; Cliff, Steve@ARB <Steve.Cliff@arb.ca.gov>
Subject: Fwd: New Report Highlights Major Concerns With Trump GHG Vehicle Emissions Proposal

FYI, this just came to me. Richard and I recently spoke about Deliberative Process / Ex. 5

Deliberative Process / Ex. 5

Chris

Christopher Grundler, Director
Office of Transportation and Air Quality
U.S. Environmental Protection Agency
202.564.1682 (Washington DC)
734.214.4207 (Ann Arbor MI)
Personal Matters / Ex. 6 (mobile)
www.epa.gov/otaq

Begin forwarded message:

> **From:** Bill Becker <bbecker744@comcast.net>
> **Date:** April 29, 2019 at 5:19:47 PM EDT
> **To:** "Grundler.Christopher@epamail.epa.gov" <Grundler.Christopher@epamail.epa.gov>
> **Subject: New Report Highlights Major Concerns With Trump GHG Vehicle Emissions Proposal**
>
> Chris—fyi
>
> I am happy to provide you with our report, released today, on the impacts of the Trump proposal to weaken vehicle GHG emissions standards. The report, *The Devastating Impacts of the Trump Proposal to Roll Back Greenhouse Gas Emissions Standards*, analyzes the rule's non-GHG emissions impacts, including smog-forming emissions, fine particles, and air toxins. Our "untold story" concludes that 1) up to 32,000 people could die prematurely and millions more get sick, 2) state and local agencies'

compliance with the Clean Air Act will be severely undermined, and 3) businesses will have difficulties expanding their operations.

I have attached a copy of the report and a press release and include a link to the report below.

Feel free to contact me if you have any questions.

Bill Becker
(Former Executive Director of the National Association of Clean Air Agencies)

https://documentcloud.adobe.com/link/track?uri=urn%3Aaaid%3Ascds%3AUS%3A72b78935-2ee6-4341-a986-8631c70f3505

Bill Becker
bbecker744@comcast.net
301-806-6111

Message

From: Cliff, Steve@ARB [Steve.Cliff@arb.ca.gov]
Sent: 4/29/2019 10:51:55 PM
To: Grundler, Christopher [grundler.christopher@epa.gov]; Corey, Richard@ARB [richard.corey@arb.ca.gov]
Subject: RE: New Report Highlights Major Concerns With Trump GHG Vehicle Emissions Proposal

Thanks

From: Grundler, Christopher <grundler.christopher@epa.gov>
Sent: Monday, April 29, 2019 3:41 PM
To: Corey, Richard@ARB <richard.corey@arb.ca.gov>; Cliff, Steve@ARB <Steve.Cliff@arb.ca.gov>
Subject: Fwd: New Report Highlights Major Concerns With Trump GHG Vehicle Emissions Proposal

FYI, this just came to me. Richard and I recently spoke about Deliberative Process / Ex. 5
Deliberative Process / Ex. 5

Chris

Christopher Grundler, Director
Office of Transportation and Air Quality
U.S. Environmental Protection Agency
202.564.1682 (Washington DC)
734.214.4207 (Ann Arbor MI)
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www.epa.gov/otaq

Begin forwarded message:

> **From:** Bill Becker <bbecker744@comcast.net>
> **Date:** April 29, 2019 at 5:19:47 PM EDT
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Bill Becker
(Former Executive Director of the National Association of Clean Air Agencies)

https://documentcloud.adobe.com/link/track?uri=urn%3Aaaid%3Ascds%3AUS%3A72b78935-2ee6-4341-a986-8631c70f3505

Bill Becker
bbecker744@comcast.net
301-806-6111

Appointment

From: Bunker, Byron [bunker.byron@epa.gov]
Sent: 4/29/2019 2:19:26 PM
To: Brooks, Phillip [Brooks.Phillip@epa.gov]; Belser, Evan [Belser.Evan@epa.gov]; Grundler, Christopher [grundler.christopher@epa.gov]; Cook, Leila [cook.leila@epa.gov]; Wehrly, Linc [wehrly.linc@epa.gov]; Hebert, Annette@ARB [annette.hebert@arb.ca.gov]; Cathey, Tawanna [Cathey.Tawanna@epa.gov]

Subject: Sidley Austin - Justin Savage
Location: C174 in Ann Arbor, Video to DC DCRoomARS1142/DC-ARIEL-RIOS-OECA-OCE, CARB via conference line

Start: 4/29/2019 3:00:00 PM
End: 4/29/2019 4:00:00 PM
Show Time As: Tentative

Conference Line: Conference Line/Code / Ex. 6
Conference ID: Conference Line/Code / Ex. 6

Message

From: Bunker, Byron [bunker.byron@epa.gov]
Sent: 4/29/2019 2:18:54 PM
To: Belser, Evan [Belser.Evan@epa.gov]; Brooks, Phillip [Brooks.Phillip@epa.gov]; Grundler, Christopher [grundler.christopher@epa.gov]; Cook, Leila [cook.leila@epa.gov]; Wehrly, Linc [wehrly.linc@epa.gov]; Hebert, Annette@ARB [annette.hebert@arb.ca.gov]; Cathey, Tawanna [Cathey.Tawanna@epa.gov]; Kaul, Meetu [Kaul.Meetu@epa.gov]
Subject: RE: Sidley Austin Self-Disclosure

Attorney Client / Ex. 5

****

Byron Bunker
Director Compliance Division
Office of Transportation and Air Quality
Environmental Protection Agency
2000 Traverwood Drive
Ann Arbor, MI 48105
Bunker.Byron@epa.gov
Phone: (734) 214-4155
Mobile: **Personal Matters / Ex. 6**

****

From: Belser, Evan
Sent: Monday, April 29, 2019 10:18 AM
To: Bunker, Byron <bunker.byron@epa.gov>; Brooks, Phillip <Brooks.Phillip@epa.gov>; Grundler, Christopher <grundler.christopher@epa.gov>; Cook, Leila <cook.leila@epa.gov>; Wehrly, Linc <wehrly.linc@epa.gov>; Hebert, Annette@ARB <annette.hebert@arb.ca.gov>; Cathey, Tawanna <Cathey.Tawanna@epa.gov>; Kaul, Meetu <Kaul.Meetu@epa.gov>
Subject: RE: Sidley Austin Self-Disclosure

Attorney Client / Ex. 5

-----Original Appointment-----
From: Bunker, Byron
Sent: Monday, April 29, 2019 10:16 AM
To: Bunker, Byron; Brooks, Phillip; Belser, Evan; Grundler, Christopher; Cook, Leila; Wehrly, Linc; Hebert, Annette@ARB; Cathey, Tawanna
Subject: Sidley Austin Self-Disclosure
When: Monday, April 29, 2019 11:00 AM-12:00 PM (UTC-05:00) Eastern Time (US & Canada).
Where: C174 in Ann Arbor, Video to DC DCRoomARS1142/DC-ARIEL-RIOS-OECA-OCE, CARB via conference line

Conference Line: **Conference Line/Code / Ex. 6**
Conference ID: Conference Line/Code / Ex. 6

Message

From: Charmley, William [charmley.william@epa.gov]
Sent: 4/25/2019 8:02:16 PM
To: steve.cliff@arb.ca.gov; Jack Kitowski (jack.kitowski@arb.ca.gov) [jack.kitowski@arb.ca.gov]; Carter, Michael@ARB [michael.carter@arb.ca.gov]
CC: Grundler, Christopher [grundler.christopher@epa.gov]
Subject: Next steps with EMA

Dear Steve, Jack and Mike –

On Monday of next week, Chris Grundler will be meeting with Jed Mandel and I believe a few of the EMA highway heavy-duty members for a one-hour discussion on the Cleaner Trucks Initiative. We did a kick-off meetings with Chris and some members of the environmental community and a separate kick-off meeting with NACAA/ECOS/APCA/NESCAUM back in February. We didn't want to have the EMA meeting with Chris until after we had the 1-day meeting with CARB in Sacramento, which we did on March 28.

Deliberative Process / Ex. 5

Deliberative Process / Ex. 5

Thanks
Bill

Message

From: Cliff, Steve@ARB [Steve.Cliff@arb.ca.gov]
Sent: 4/22/2019 7:12:21 PM
To: Charmley, William [charmley.william@epa.gov]; Grundler, Christopher [grundler.christopher@epa.gov]
Subject: RE: Tuesday's meeting with EMA

Thanks Bill.

From: Charmley, William <charmley.william@epa.gov>
Sent: Monday, April 22, 2019 12:08 PM
To: Grundler, Christopher <grundler.christopher@epa.gov>; Cliff, Steve@ARB <Steve.Cliff@arb.ca.gov>
Subject: FW: Tuesday's meeting with EMA

Dear Chris and Steve,

Deliberative Process / Ex. 5

Thanks

Bill

From: Charmley, William
Sent: Monday, April 22, 2019 1:10 PM
To: Jack Kitowski (jack.kitowski@arb.ca.gov) <jack.kitowski@arb.ca.gov>; Carter, Michael@ARB <michael.carter@arb.ca.gov>; Kim A. Heroy-Rogalski <kim.heroy-rogalski@arb.ca.gov>; Lemieux, Stephan@ARB <stephan.lemieux@arb.ca.gov>
Cc: Nelson, Brian <nelson.brian@epa.gov>; Kathryn Sargeant (sargeant.kathryn@epa.gov) <sargeant.kathryn@epa.gov>; Parsons, Christy <Parsons.Christy@epa.gov>; James Sanchez (sanchez.james@epa.gov) <sanchez.james@epa.gov>; Brakora, Jessica <Brakora.Jessica@epa.gov>
Subject: Tuesday's meeting with EMA

Dear Jack, Mike, Kim and Stephan,

Deliberative Process / Ex. 5

Deliberative Process / Ex. 5

Deliberative Process / Ex. 5

Deliberative Process / Ex. 5

Deliberative Process / Ex. 5

Deliberative Process / Ex. 5

Jack – you asked me on Friday if I thought we could have time at the end of the day on Tuesday for a discussion with the ARB staff regarding the substance of what is discussed on Tuesday.

Deliberative Process / Ex. 5

Thanks
Bill

Message

From: Charmley, William [charmley.william@epa.gov]
Sent: 4/22/2019 7:07:54 PM
To: Grundler, Christopher [grundler.christopher@epa.gov]; steve.cliff@arb.ca.gov
Subject: FW: Tuesday's meeting with EMA

Dear Chris and Steve,

Deliberative Process / Ex. 5

Thanks

Bill

From: Charmley, William
Sent: Monday, April 22, 2019 1:10 PM
To: Jack Kitowski (jack.kitowski@arb.ca.gov) <jack.kitowski@arb.ca.gov>; Carter, Michael@ARB <michael.carter@arb.ca.gov>; Kim A. Heroy-Rogalski <kim.heroy-rogalski@arb.ca.gov>; Lemieux, Stephan@ARB <stephan.lemieux@arb.ca.gov>
Cc: Nelson, Brian <nelson.brian@epa.gov>; Kathryn Sargeant (sargeant.kathryn@epa.gov) <sargeant.kathryn@epa.gov>; Parsons, Christy <Parsons.Christy@epa.gov>; James Sanchez (sanchez.james@epa.gov) <sanchez.james@epa.gov>; Brakora, Jessica <Brakora.Jessica@epa.gov>
Subject: Tuesday's meeting with EMA

Dear Jack, Mike, Kim and Stephan,

Deliberative Process / Ex. 5

Deliberative Process / Ex. 5

Deliberative Process / Ex. 5

Deliberative Process / Ex. 5

Jack – you asked me on Friday if I thought we could have time at the end of the day on Tuesday for a discussion with the ARB staff regarding the substance of what is discussed on Tuesday.

Deliberative Process / Ex. 5

Thanks
Bill

Appointment

From: Wang, Lee@ARB [Lee.Wang@arb.ca.gov]
Sent: 4/19/2019 4:16:03 PM
To: Baumgard Kirby J [BaumgardKirbyJ@JohnDeere.com]; Beth Hinchee [Hinchee_Beth_A@cat.com]; Brian Bolton [Brian.Bolton@hmmusa.com]; ellis [ellis@hino.com]; Aaron Neuman [Aaron.Neuman@Daimler.com]; Cullen, Angela [cullen.angela@epa.gov]; Anne-Marie Williams [Anne-Marie.Williams@Navistar.com]; Arvind Thiruvengadam [Arvind.Thiruvengadam@mail.wvu.edu]; Benjamin C. Shade [benjamin.shade@avl.com]; Brent Keppy [Brent.Keppy@us.bosch.com]; Carl Beck [carl.beck@volvo.com]; Charles Benoit Chaumette [Charles-benoit.Chaumette@Daimler.com]; Chris Lemansky [Chris.Lemanski@Daimler.com]; cshimoda@caltrux.org; Chris Wright [Chris.Wright@PACCAR.com]; Costi Nedelcu [costi.nedelcu@paccar.com]; Craig Kazmierczak [Craig.Kazmierczak@Daimler.com]; Daniel Moote [daniel.moote@daimler.com]; Daniel Young [daniel.young@continental-corporation.com]; Dave Polivka [Dave.Polivka@Navistar.com]; David Kayes [David.Kayes@Daimler.com]; David Piech [david.piech@cnhind.com]; Dr. Ameya Joshi [JoshiA@corning.com]; Dr. Tue Johannessen [TJ@amminex.com]; Eric Persson [eric.persson@avl.com]; Francisco Posada [francisco@theicct.org]; Frank Seymour [Francis.Seymour_Jr@daimler.com]; Geisick Bryan T [GeisickBryanT@JohnDeere.com]; Geoff Johnson [geoff.johnson2@canada.ca]; George Lin [Lin_George@cat.com]; Mitchell, George [Mitchell.George@epa.gov]; Greg Siuchta [Gregory.Siuchta@Navistar.com]; Hammoud, Rime (EC [rime.hammoud@canada.ca]; Heejung Jung [heejung@engr.ucr.edu]; Heltzel Robert [robert.heltzel@volvo.com]; Jack MacDonnell [jmacdonnell@enermotion.com]; Jackie Yeager [jackie.m.yeager@cummins.com]; James Cigler [James.Cigler@Navistar.com]; James Konstant [Jim.Konstant@Navistar.com]; Jason Pless [Jason.Pless@jmusa.com]; Jeff Zsoldos [jeffrey.zsoldos@volvo.com]; Joanna Bellamy [joanna.bellamy@canada.ca]; Joh Hart [John.Hart@stoneridge.com]; Josephine Davidson [Josephine.davidson@canada.ca]; Julie Deschatelets [Julie.deschatelets@canada.ca]; Kim Hradecky [kimberly.hradecky@canada.ca]; Martin Romzek [Martin.Romzek@eberspaecher.com]; Matt Spears [spears.matthew@epa.gov]; Matthew R. Smith [Matt.Smith@Navistar.com]; Rajani Modiyani [rajani.modiyani@cummins.com]; Robin Willats [robin.willats@faurecia.com]; Sam George [GeorgeS@corning.com]; Shirish Shimpi [shirish.a.shimpi@cummins.com]; Steve Musselman [Steven.Musselman@Daimler.com]; Thomas Lawson [Thomas@cngvc.org]; Timothy A. French [tfrench@emamail.org]; Tom Durbin [durbin@cert.ucr.edu]; Victor Miranda [victor.miranda@navistar.com]; Xavier Faucon [FauconXavier@JohnDeere.com]; Chris Sharp [chris.sharp@swri.org]; Gurpreet Singh [Gurpreet.Singh@ee.doe.gov]; Ken Howden [Ken.Howden@ee.doe.gov]; Robert Wagner [wagnerrm@ornl.gov]; jkubsh@meca.org; Mike Geller [mgeller@Meca.org]; rbrezny@meca.org; Timothy French [tfrench@clpchicago.com]; Jeff Marley [jeff.marley@volvo.com]; 'He Yuesheng' [yuesheng.he@volvo.com]; Berry Steve [steve.berry@volvo.com]; dan.kieffer@paccar.com; Don Keski-Hynnila [donald.keski-hynnila@daimler.com]; Don Stanton [donald.w.stanton@cummins.com]; 'Lisa A Farrell' [lisa.a.farrell@cummins.com]; Russ Zukouski [russ.zukouski@navistar.com]; Laroo, Chris [laroo.chris@epa.gov]; Matthew Spears [mspears@emamail.org]; Zhang, Houshun [Zhang.Houshun@epa.gov]; Nelson, Brian [nelson.brian@epa.gov]; Sanchez, James [sanchez.james@epa.gov]; Yanca, Catherine [yanca.catherine@epa.gov]; aoshinuga@aqmd.gov; Joseph Lopat [jlopat@aqmd.gov]; Thornton, Matthew [Matthew.Thornton@nrel.gov]; Duran, Adam [Adam.Duran@nrel.gov]; Adam Kotrba [AKotrba@Tenneco.com]; Kevin Hallstrom [kevin.hallstrom@basf.com]; Dave Cetola [david.cetola@jmusa.com]; Mark Monohon – [MMonohon@ngksparkplugs.com]; Magana, Pilar@Energy [Pilar.Magana@energy.ca.gov]; Wiens, Jerry@Energy [Jerry.Wiens@energy.ca.gov]; Wiens, Jerry [jwiens@surewest.net]; Magnusson Mathias [mathias.magnusson.2@volvo.com]; Tasik Karl [karl.tasik@volvo.com]; David M Youngren [dave.youngren@basf.com]; jason.martin@daimler.com; Miller Marc [marc.miller@volvo.com]; Anderson Rickey [rickey.anderson@volvo.com]; igor.gruden@daimler.com; jason.barton@daimler.com; jeffrey.murawa@daimler.com; inderpal.singh@daimler.com; Janak, Robb [Robb.Janak@jakebrake.com]; Brian C Mormino [brian.c.mormino@cummins.com]; Landon Sproull [Landon.Sproull@PACCAR.com]; Clark Taylor [taylor.clark@volvo.com]; Mclaughlin Samuel [samuel.mclaughlin@volvo.com]; jeff.foor@fcagroup.com; Razaznejad Behrooz [behrooz.razaznejad@volvo.com]; David B. Brown [david.b.brown@gm.com]; Andersson Lennart (la [lennart.la.andersson@volvo.com]; Gibble John [john.gibble@volvo.com]; Istenes Raymond [raymond.istenes@volvo.com]; Zhang, Chen [Chen.Zhang@nrel.gov]; Miller, Eric [Eric.Miller@nrel.gov]; Kelly, Kenneth [Kenneth.Kelly@nrel.gov]; Mike Gerty [Mike.Gerty@PACCAR.com]; Gui Xinqun [GuiXinqun@JohnDeere.com]; Carlhammar Lars [Lars.Carlhammar@volvo.com]; Matt Stefanick [Stefanick_Matt@cat.com]; toma.codreanu@daimler.com; Lowry, Jeff@ARB [jeffrey.lowry@arb.ca.gov]; alessandro.cozzolini@daimler.com; Hawelti, Daniel@ARB [daniel.hawelti@arb.ca.gov]; Lemieux, Stephan@ARB [stephan.lemieux@arb.ca.gov]; Heroy-Rogalski, Kim@ARB [kim.heroy-rogalski@arb.ca.gov]; Robertson, Bill@ARB [bill.robertson@arb.ca.gov]; Carter, Michael@ARB [michael.carter@arb.ca.gov]; Kitowski, Jack@ARB

[jack.kitowski@arb.ca.gov]; Adnani, Paul@ARB [Paul.Adnani@arb.ca.gov]; Bartolome, Christian@ARB [Christian.Bartolome@arb.ca.gov]; Santos, Alex@ARB [Alex.Santos@arb.ca.gov]; O'Connor, Susan@ARB [susan.o'connor@arb.ca.gov]; Haste, Ron@ARB [Ron.Haste@arb.ca.gov]; Richards, Nadia@ARB [Nadia.Richards@arb.ca.gov]; Lee, Abraham@ARB [abraham.lee@arb.ca.gov]; O'Cain, John@ARB [John.O'Cain@arb.ca.gov]; Tan, Yi@ARB [Yi.Tan@arb.ca.gov]; Herner, Jorn@ARB [jorn.herner@arb.ca.gov]; Yoon, Seungju@ARB [seungju.yoon@arb.ca.gov]; Montes, Thomas@ARB [thomas.montes@arb.ca.gov]; Pazokifard, Babak@ARB [Babak.Pazokifard@arb.ca.gov]; Pryor, Kimberly@ARB [Kim.Pryor@arb.ca.gov]; Lourenco, Jackie@ARB [Jackie.Lourenco@arb.ca.gov]; Regenfuss, Mike@ARB [michael.regenfuss@arb.ca.gov]; Chang, Hung-Li@ARB [hungli.chang@arb.ca.gov]; Jaw, Kathy@ARB [Kathy.Jaw@arb.ca.gov]; Lemieux, Sharon@ARB [sharon.lemieux@arb.ca.gov]; ARB MSCD Meetings And Events [600.mscdcal.ARB@arb.ca.gov]

CC: Wong, Jeffrey@ARB [jwong@arb.ca.gov]; Mahmood, Adil@ARB [Adil.Mahmood@arb.ca.gov]; Ho, Jerry@ARB [Jerry.Ho@arb.ca.gov]; Macias, Keith@ARB [keith.macias@arb.ca.gov]; Vincent Ngo [Vincent.Ngo@arb.ca.gov]; Charmley, William [charmley.william@epa.gov]; timdenoyer@gmail.com; Kenny Vieth [kwvieth@actresearch.net]; Matthew Psota [matthew.psota@cummins.com]; Tim Denoyer [tdenoyer@actresearch.net]; Baltrucki, Justin [Justin.Baltrucki@jakebrake.com]; Weaver Ron [ron.weaver@volvo.com]; Jeff Marsee [Jeff.Marsee@isza.com]; ken.degroot@fcagroup.com; Kevin Fan [KFan@Tenneco.com]; Steve Rubenstein [SRubenstein@Tenneco.com]; Kathleen Horchler [Horchler_Kathleen@cat.com]; frank.krich@fcagroup.com; David W Lake [david.w.lake@gm.com]; dawn.fenton@volvo.com; Hebert, Annette@ARB [annette.hebert@arb.ca.gov]; Grundler, Christopher [grundler.christopher@epa.gov]; jeffrey.girbach@daimler.com; dan.potter@daimler.com; James Hall [jamie.hall@gm.com]; Lyons, Allen@ARB [allen.lyons@arb.ca.gov]

Subject: CARB Low NOx Workgroup Meeting
Location: Exc (AN1)

Start: 5/7/2019 5:00:00 PM
End: 5/7/2019 7:00:00 PM
Show Time As: Tentative

Recurrence: (none)

Update 4/19/19

This meeting has been postponed to provide stakeholders enough time to review the White Paper.
The link to the White Paper is https://www.arb.ca.gov/msprog/hdlownox/white_paper_04182019a.pdf

Online Meeting/Conference Call Information:

https://attendee.gotowebinar.com/register/ **Conference Line/Code / Ex. 6**
Dial-in Number: **Conference Line/Code / Ex. 6**
Passcode: **Conference Line/Code / Ex. 6**

Meeting Purpose:

CARB staff is in the process of developing a comprehensive rulemaking that would revise various elements of the current emission regulations for on-road heavy-duty vehicles. These proposed revisions would include more stringent standards for NOx emissions, revised certification test procedures including a new supplemental low load cycle, amendments to the emission averaging, banking and trading program, amendments to warranty length and useful life periods, updated certification durability demonstration requirements, revisions to the heavy-duty in-use testing program, and revisions to warranty rate based corrective action.
To provide manufacturers with some insight going forward as they lock in designs to meet 2024 MY Phase 2 GHG standards, CARB plans to release a white paper during the week of 4/15/2019. This paper will be CARB staff's assessment of what is achievable in a cost-effective manner with engines for MY's 2024-2026, as well as 2027 and beyond.

In this meeting, CARB will discuss the content of the paper and solicit feedback from stakeholders. Also, CARB will provide an update on the proposed concepts on useful life and step 2 warranty.

Meeting Agenda:

1. Introduction (10 min)
2. CARB White Paper
   a. Presentation – 20 minutes
   b. Discussion – 40 minutes
3. Update on Proposed Useful Life and Step 2 Warranty Concepts
   a. Presentation – 20 minutes
   b. Discussion – 20 minutes
4. Next Steps (10 min)

External Attendees

SwRI, NREL, EMA, MECA, Daimler, Navistar, Paccar, Caterpillar, Cummins, John Deere, FCA US, Volvo, Hino, Ford, CTS Corp., CNH Industrial, MECA, US EPA, CEC, US DOE, ORNL, SCAQMD, , CEC, ORNL, Environment and Climate Change Canada, Taiwan EPA, ICCT, WVU, UCR, AVL, Bosch, Continental Corporation, Johnson Matthey, Corning, EnerMotion, Stoneridge, Eberspächer, Faurecia, Corning, Tenneco, BASF, Jacobs Vehicle Systems, NGK, California NGV Coalition, ATA CTA, Western States Trucking Association, Ellison Wilson Advocacy, LLC, California Fleet Solutions.

CARB Contacts

Daniel Hawelti, (626) 450-6149, daniel.hawelti@arb.ca.gov
Lee Wang, (626) 450-6145, lee.wang@arb.ca.gov

Message

From: Cliff, Steve@ARB [Steve.Cliff@arb.ca.gov]
Sent: 4/18/2019 10:31:28 PM
To: Grundler, Christopher [grundler.christopher@epa.gov]
Subject: low-NOx white paper
Attachments: Heavy-Duty Low NOx White Paper-04182019A.pdf

In all its glory. Will be posted shortly, and I think staff sends a listserv.

Staff White Paper

California Air Resources Board Staff Current Assessment of the Technical Feasibility of Lower NOx Standards and Associated Test Procedures for 2022 and Subsequent Model Year Medium-Duty and Heavy-Duty Diesel Engines

Prepared by Staff of the
Mobile Source Control Division
Mobile Source Regulatory Development Branch

April 18, 2019

State of California
California Air Resources Board

This report has been prepared by the staff of the California Air Resources Board. Publication does not signify that the contents reflect the views and policies of the California Air Resources Board, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

Table of Contents

I. Background

Exposure to fine particulate matter (PM2.5) and ozone is associated with premature death, increased hospitalizations and emergency room visits due to exacerbation of chronic heart and lung diseases, and other serious health impacts. As a toxic air contaminant, diesel PM poses especially serious health risks.

Although California has made significant progress in improving air quality over the past five decades, over 12 million California residents still breathe unhealthy air. The South Coast still has the highest ozone levels in the nation while the San Joaquin Valley has the greatest PM2.5 challenge. The South Coast and San Joaquin Valley are the only two extreme ozone areas in the nation, with an attainment deadline of 2031.[1] The San Joaquin Valley's attainment dates for the 24-hour and annual PM2.5 standards are 2024 and 2025, respectively. The health and economic impacts of exposure to elevated levels of ozone and PM2.5 in California are considerable; meeting national ambient air quality standards will pay substantial dividends in terms of reducing costs associated with emergency room visits and hospitalization, lost work and school days, and most critically, premature mortality. Reductions in diesel PM will further reduce statewide cancer risk and non-cancer health effects, especially for residents living near major sources of diesel emissions such as ships, trains, and trucks, operating in and around ports, rail yards, and heavily traveled roadways.

To meet the 2023 and 2031 national ambient air quality standards for ozone, the South Coast Air Basin will require an approximate 70 percent oxides of nitrogen (NOx) reduction from today's levels by 2023 and 80 percent NOx reduction by 2031. Since NOx is also a precursor to secondary PM2.5 formation, reductions in NOx emissions will also provide benefits for meeting the PM2.5 standards.

Heavy-duty trucks over 10,000 pounds gross vehicle weight rating (GVWR) are significant contributors to the formation of ozone, PM2.5, and diesel particulate matter emissions in California. For example, they are responsible for over 70 percent of NOx emissions from on-road mobile sources.[2] Exacerbating the challenge of cutting overall emissions, the number of vehicles and associated vehicle miles traveled have been continuously increasing each year. In order to meet California's air quality goals, despite the progress made, further reductions of heavy-duty truck NOx emissions are necessary.

The California Air Resources Board's (CARB or Board) strategy in reducing emissions from heavy-duty vehicles relies on a multipronged approach of regulatory and voluntary incentive programs that include establishing emissions and performance standards for new vehicles and engines, setting mandates and sales requirements for advanced

[1] The South Coast attainment dates are 2023 for the 80 ppb 8-hour ozone standard, and 2031 for the 75 ppb 8-hour ozone standard. 2008 National Ambient Air Quality Standards (NAAQS) for Ozone (https://www.epa.gov/ground-level-ozone-pollution/2008-national-ambient-air-quality-standards-naaqs-ozone)

[2] Estimate based on 2019 calendar year heavy-duty vehicle inventory: CEPAM: 2016 SIP - Standard Emission Tool (https://www.arb.ca.gov/app/emsinv/fcemssumcat2016.php)

technologies, developing pilot programs, and implementing incentive and other programs to accelerate technology deployment (see Figure 1). In order to meet our air quality goals and GHG emission and petroleum use reduction targets, CARB is aiming to encourage the use of zero emission vehicles and equipment where possible, while simultaneously ensuring conventional technologies are as low-emitting as feasible. CARB has already approved the Innovative Clean Transit Regulation, for example, which requires public transit agencies to gradually transition to 100 percent zero-emission bus fleets by 2040.[3] Staff is also in the process of developing proposals for new heavy-duty vehicle strategies to achieve the transition from conventional combustion technologies to zero emission technology for vehicle applications that are best suited for zero emission technology.[4] The Heavy-Duty Low NOx program,[5] which is the subject of this white paper, is part of CARB's overall strategy to establish more stringent emission standards and in-use performance requirements to reduce emissions from heavy-duty combustion technologies. Together, these approaches are designed to achieve progressively cleaner in-use fleet emission levels.

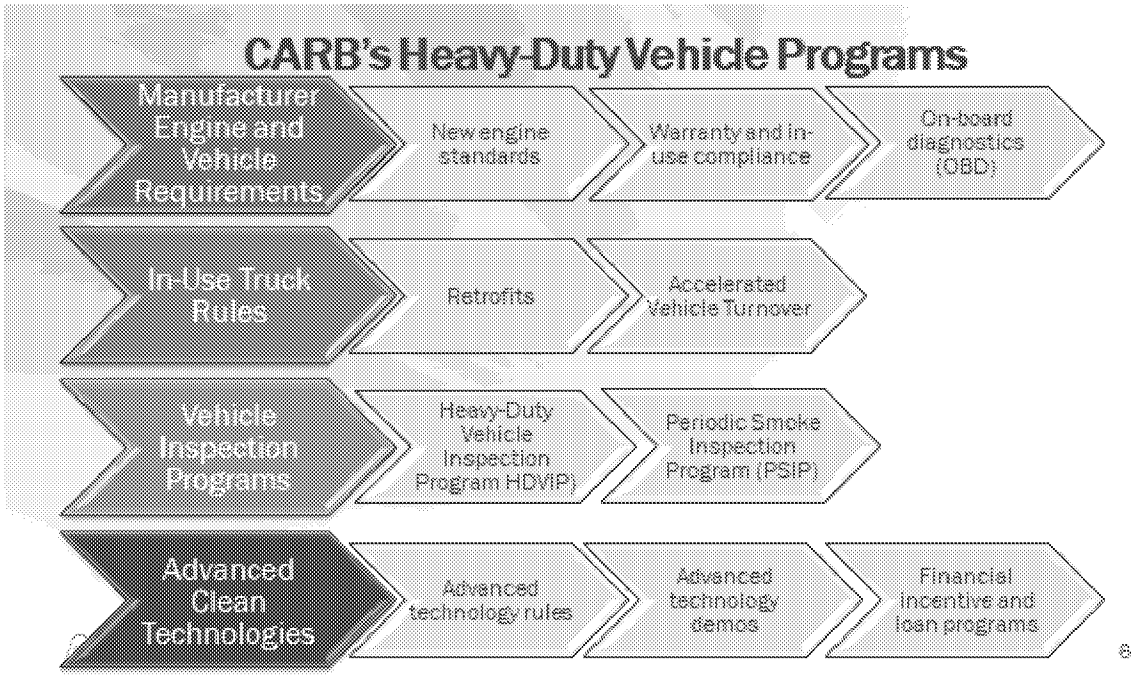

Figure 1 – CARB's Heavy-Duty Vehicles Programs

Over the last three decades, NOx and PM emission standards for heavy-duty on-road engines have become more stringent. For NOx, the standard has decreased from 6.0 grams per brake horsepower hour (g/bhp-hr) in 1990 to the current 0.20 g/bhp-hr standard in 2010. For PM, the standard has decreased from 0.6 g/bhp-hr in 1990 to 0.01 g/bhp-hr in 2010. In addition to the increasingly stringent standards, California has also adopted programs that provide substantial in-use emissions reductions such as

[3] Innovative Clean Transit program webpage: https://www.arb.ca.gov/msprog/ict/ict.htm

[4] Advanced Clean Truck program webpage: https://ww2.arb.ca.gov/our-work/programs/advanced-clean-truck

[5] Heavy-Duty Low NOx program webpage: https://www.arb.ca.gov/msprog/hdlownox/hdlownox.htm

vehicle idling restrictions and in-use fleet rules, including the Drayage Truck Regulation and the Truck and Bus Regulation. These fleet rules require the upgrade of older trucks and buses to newer, cleaner engines meeting the 2010 standards by 2023. To comply with these regulations, fleets have made substantial investments to purchase lower-emitting vehicles.

In 2013, CARB established optional low-NOx standards with the most stringent optional standard being 0.02 g/bhp-hr, which is a 90 percent reduction from the current standard. The optional low-NOx standards were developed to encourage the development of cleaner engines and improved emission control systems, paving the way for setting future standards. In addition, incentive programs were developed to further encourage the development of advanced engine and aftertreatment systems and, to-date, 10 natural gas or liquefied petroleum gas engines have been certified to the 0.02 g/bhp-hr optional NOx standard.

In March 2017, the Board approved the 2016 State Strategy for the State Implementation Plan (SIP).[6] One of the key measures in the SIP is the establishment of on-road heavy-duty low-NOx engine emission requirements that would provide a 90 percent reduction in NOx emissions compared to today's engines. To complement this measure, the SIP also included a "Lower In-Use Emission Performance Level" measure that would ensure that heavy-duty vehicles remain "clean" in-use, as they were originally certified when new. These two measures are critical for attaining federal health-based air quality standards for ozone in 2031 in the South Coast and San Joaquin Valley air basins, as well as PM2.5 standards in the next decade.

Because trucks that were newly purchased outside of California accrue about 60 percent of total heavy-duty vehicle miles traveled in the South Coast on any given day, it is critical that the U.S. Environmental Protection Agency (U.S. EPA) take action to establish a new national low-NOx standard for heavy-duty trucks.[7] In response to petitions for a low-NOx rulemaking from over 20 organizations, including state and local air agencies from across the country, on November 13, 2018, U.S. EPA announced the "Cleaner Trucks Initiative" to develop regulations to further reduce NOx emissions from on-road heavy-duty trucks and engines. U.S. EPA intends to publish a proposed rule in 2020.[8]

Staff has been working on developing new significantly lower NOx emission standards and other strategies to implement the SIP measures described above. Specifically, the proposed changes include development of new NOx emission standards on existing certification cycles such as the Federal Test Procedure (FTP) and the Supplemental Emission Test Ramped Modal Cycle (RMC-SET); the development of a new certification

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[6] Proposed 2016 State Strategy for the State Implementation Plan. May 17, 2016 (https://www.arb.ca.gov/planning/sip/2016sip/2016sip.htm)

[7] https://www.epa.gov/regulations-emissions-vehicles-and-engines/petitions-revised-nox-standards-highway-heavy-duty
https://www.epa.gov/sites/production/files/2016-12/documents/additional-petitioners.pdf

[8] EPA Acting Administrator Wheeler Launches Cleaner Trucks Initiative. https://www.epa.gov/newsreleases/epa-acting-administrator-wheeler-launches-cleaner-trucks-initiative

low load cycle (LLC) and associated NOx emission standard; revisions to the Not-to-Exceed (NTE) Heavy-Duty In-Use Testing (HDIUT) program; lengthening the useful life and warranty periods; clarifications to warranty corrective action provisions; and revisions to the durability demonstration procedures. Staff is preparing to bring a proposal to the Board for a comprehensive well-integrated Heavy-Duty Low NOx rule incorporating all the aforementioned elements, referred to as the "Heavy-duty Low NOx Omnibus Rulemaking," in the first quarter of 2020.

To support the development of these new requirements, CARB, in partnership with the South Coast Air Quality Management (SCAQMD), U.S. EPA, and the Manufacturers of Emission Controls Association (MECA) has been funding several research programs with Southwest Research Institute (SwRI) to demonstrate the feasibility of lower NOx emissions from on-road heavy-duty engines. The results from Stage 1[9] of the SwRI program were published in April 2017 and helped inform staff's feasibility assessment for model year (MY) 2024. The final results from Stages 2 and 3 of the SwRI research program are expected to become available during the third or fourth quarter of 2019. Stage 2 is a continuation of the Stage 1 program and its objectives include the development of an LLC (potentially to be used as a certification cycle), optimization of the Stage 1 engine-aftertreatment system (EAS) under low load operations, and development of in-use measurement metrics under low loads. Stage 3 is a low NOx demonstration program using a newer model engine and includes optimization of an EAS under the certification and vocational cycles including the low load cycles developed in Stage 2. Stages 2 and 3 will help inform staff regarding the feasible level of emissions standards for the FTP, RMC-SET, and LLC, and the heavy-duty in-use testing program applicable for 2027 and subsequent MY engines.

Historically, it has been assumed that the establishment of laboratory emission standards and manufacturer compliance with those standards would result in emission reduction trends in the real world. However, as CARB staff has investigated over-the-road emissions with the use of Portable Emissions Measurement Systems, tallied emission warranty claims reflective of non-durable parts, and examined the effectiveness of current processes and test procedures to implement the heavy-duty emission standards over the past several years, it has become clear that the expected emissions reductions from the adoption of our laboratory emissions standards have not been fully realized in the real world. Although the actual emission rates of engines in the field will always vary depending on the specific duty cycle of the engine, adding a new LLC to the already existing FTP and RMC-SET requirement will provide certification test results that more accurately capture the range of real-world activity. In addition, CARB must shore up implementation and compliance programs to ensure the total emission benefits envisioned with a laboratory based certification emission standards are attained and reflected in real world emission performance. Thus, the potential regulatory elements described in this paper extend beyond just a proposed certification emission standard.

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[9] Sharp, C.A., Webb, C.C., Neely, G.D, Smith, I., "Evaluating Technologies and Methods to Lower Nitrogen Oxide Emissions from Heavy-Duty Vehicles", Southwest Research Institute (SwRI) Project No. 19503 Final Report (2017). (https://www.arb.ca.gov/research/single-project.php?row_id=65182)

During the last several years, staff has been reaching out to stakeholders by holding workshops, workgroup meetings, meetings with industry associations and individual one-on-one meetings with engine manufacturers and technology providers. Since November 2016, CARB has held two public workshops and five workgroup meetings. Furthermore, staff met with the heavy-duty industry's Truck and Engine Manufacturers Association (EMA) and individually with the major engine manufacturers multiple times to discuss the planned rulemaking, seek their input, and listen to their overall concerns. At the workgroup meetings and the most recent January 2019 workshop, CARB staff presented to stakeholders detailed concepts on several of these regulatory elements such as changes to the HDIUT program, new durability demonstration procedures, and lengthened useful life and warranty periods.

II. Purpose of this White Paper

The main objective of this white paper is to outline staff's assessment regarding technical feasibility and cost effectiveness of possible NOx reduction programs for 2022 and subsequent MY diesel medium-duty and heavy-duty engines.[10] Although some elements of the Heavy-duty Low NOx Omnibus Rulemaking will affect medium-duty and heavy-duty Otto cycle engines as well, this white paper focuses solely on an assessment for diesel engines.

During recent meetings, many engine manufacturers indicated that they are in the process of settling on engine design and development plans to meet the 2024 MY Phase 2 greenhouse gas (GHG) requirements.[11] They further indicated that, in order to accommodate NOx reductions on the same hardware platform, engine manufacturers have requested feedback in terms of staff's thinking for any nearer term (2022-2023 MY) amendments to existing programs as soon as possible. They have repeatedly emphasized the need for sufficient product development time to incorporate NOx requirements along with the Phase 2 GHG requirements. This white paper is intended to provide a technical response to these requests.

It is important to emphasize that this white paper is strictly staff's current assessment of what is currently considered as technically achievable and cost effective for 2022 and subsequent model years. As additional and/or updated technical information becomes available between now and the Board hearing date, and because the Board has the ultimate authority to accept, reject, or change staff's proposal as it sees fit, this white

[10] This white paper is applicable only to heavy-duty and medium-duty engines certified through Title 13, California Code of Regulations, Section 1956.8. It covers engines for use in vehicles over 10,000 pound gross vehicle weight rating (GVWR).

[11] The Phase 2 standards for medium- and heavy-duty engines and vehicles are implemented in three steps: 2021, then 2024, and then 2027. See California Greenhouse Gas Emissions Standards for Medium- And Heavy-Duty Engines and Vehicles (Phase 2) (https://www.arb.ca.gov/msprog/onroad/caphase2ghg/caphase2ghg.htm)

paper cannot predict with certainty what CARB will ultimately adopt in its Heavy-duty Low NOx Omnibus Rulemaking.

III. CARB Staff Assessment

Based on a survey of current baseline engine certification emission levels and CARB co-sponsored research programs, staff is considering a three-step phase-in for the low NOx program. In order to minimize the burden on product development cycles, staff believes synchronizing the implementation dates for the low NOx regulations with the Phase 2 GHG implementation dates would be advantageous. These three steps are described in detail below.

Step 1 (2022-2023 MY)

The key components of Step 1 are outlined in Table 1 below. Step 1 mainly involves changing the limits on the carve-out regions for the NTE method, and the requirement to perform HDIUT emission calculations and report the data using the modified Euro VI(D) method.

Staff believes that, based on current NOx control technologies implemented on 2010 and later MY engines and the universal availability of ultra low sulfur diesel fuel, several of the existing carve-outs in the NTE are antiquated, unnecessary and hence feasible to remove for MY 2022 and later. Staff also believes it is feasible for manufacturers to begin performing HDIUT emission calculations and reporting the data using the modified Euro VI(D) method, which is based on a moving average window (MAW) approach.[12]

Staff is also planning to revise the regulatory language for the Emission Warranty Information Reporting program to further clarify existing CARB requirements and accelerate the timeline for corrective action when emissions problems are found.

Step 2 (2024-2026 MY)

Table 2 provides a summary of the Step 2 program elements. Staff believes that all of the requirements in Step 2 can be met without the introduction of any major engine hardware changes, but they would likely require changes to engine calibration and the emission aftertreatment system.

Staff believes a reduction to the NOx and PM emissions standards is feasible, along with the introduction of a new certification LLC in Step 2. A reduction of the clean idle NOx standard and adoption of the modified MAW-based Euro VI(D) program for HDIUT are also considered feasible in this timeframe.

Other programmatic changes include the requirement for full useful life (UL) aging of engine and aftertreatment systems for durability demonstration, with the option to use

[12] Compliance determinations during this period will be based on the current NTE method with minor modifications to the carve-out region and limits.

accelerated aftertreatment aging for a portion of useful life. Staff also believes the periodic submittal of NOx sensor data from in-use vehicles is feasible and would be helpful in order to evaluate a future alternative durability program that relies on a combination of dynamometer aging, accelerated aftertreatment aging, and NOx sensor reporting. The objective of the alternative durability program would be to reduce upfront certification durability requirements and rely more on reporting of in-use data. The periodic NOx sensor reporting from Step 2 would be essential in validating any future alternative durability programs.

Finally, CARB and U.S. EPA have historically endeavored to harmonize their emissions requirements for heavy-duty engines, in recognition of the fact that such harmonization allows the industry to design and produce a single set of engines for use throughout the nation. If such harmonization is not possible, there may be a need for California to establish a California-only bank for emission credits. If so, there would be restrictions and sunset provisions included in the California-only bank.

It should be noted that 2024-2026 MY low NOx implementation dates would coincide with the second part of Phase 2 GHG implementation dates. This would allow the engine manufacturers to introduce the necessary calibration and hardware changes for low NOx and GHG simultaneously.

Step 3 (2027 and subsequent MYs)
A summary of potential Step 3 requirements is provided in Table 3 below. Staff believes that the future emission standards in Step 3 would likely require the introduction of engine hardware upgrades, but the 2027 MY implementation date would provide sufficient lead-time for product development and design.

At this point, it is essential to note that staff does not have sufficient data to provide specific details on what may be technically achievable and cost effective in 2027 and subsequent model years. Key inputs to the proposal for MY 2027 and beyond are anticipated to become available from the ongoing heavy-duty NOx demonstration program underway at the SwRI.

Although specific details are not currently available, CARB plans to introduce another set of more stringent NOx emissions standards applicable for 2027 and subsequent MYs, as well as further enhancements to the in-use testing program, warranty, and useful life requirements. Once again, it should be noted that the final Phase 2 GHG implementation dates and Step 3 implementation dates are synchronized to reduce the burden on product development.

Table 1 – CARB Staff Assessment of Feasible Standards and Requirements for MY 2022 and 2023

2022 and 2023 MY Engines Assessment (Heavy-Duty and Medium-Duty Engines for > 10,000 pounds GVWR)	
NOx Standards	Existing FTP, RMC-SET and idling standards
HDIUT	1) Continuing with current NTE method with the following changes: - Modify Cold Temperature Operation - Ambient Temperature Exclusion ≤ 7°C 2) Reporting of all data including a compliance evaluation report required by the modified moving average window-based Euro VI(D)[13] method planned for 2024 MY engines. Compliance determinations would be based on the NTE method (see also Appendix 1b)
Durability Demonstration Program	CARB certification staff continuing to work individually with manufacturers and EMA on issues related to their durability demonstration programs.
Emission Warranty Information Reporting (EWIR)	1) Basing the need for corrective action solely on warranty claim rates 2) Adding compliance with EWIR and corrective action as a condition under which the Executive Order is granted to help ensure expeditious action by the manufacturer 3) Other clarifying items as discussed in the workshop presentation of 1/23/2019 (See Appendix 2 for presentation slides)

[13] COMMISSION REGULATION (EU) No 582/2011, May 25, 2011 (https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02011R0582-20180118&from=EN); and COMMISSION REGULATION (EU) 2018/932, June 29, 2018 (https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018R0932&from=EN)

Table 2 – CARB Staff Assessment of Feasible Standards and Requirements for MYs 2024 through 2026

2024 through 2026 MY Engines Assessment (Heavy-Duty and Medium-Duty Engines for > 10,000 pounds GVWR)	
NOx standards	1) 0.05 to 0.08 g/bhp-hr NOx on the FTP and RMC-SET 2) (1 to 3) x FTP = (0.05 to 0.24 g/bhp-hr) NOx on the LLC[14] 3) 10 g/hr NOx idling standard (controlled within 5 minutes of cold start)
PM standards	0.005 g/bhp-hr PM on the composite FTP and RMC-SET
HDIUT	1) Compliance based on modified moving average window-based Euro VI(D) method (replacing current NTE method) (See Appendix 1a) - Conformity factor: 1.5 - In-use threshold: 1.5 x FTP Standard - Regular customer route - Pre-approval of test plan: operation type, location, etc. - Manufacturer could invalidate test day if over 50% of windows are below 10% of engine's peak power. Retest until a valid test day is completed 2) Pilot program to demonstrate how the collection and reporting of on-board diagnostic data (e.g., Real Emissions Assessment Logging (REAL) data) could be used as an alternative compliance option.
Durability Demonstration Program	Three options: 1) Full UL EAS aging with defined cycles on an engine dynamometer (see Appendix 3 for further detail). 2) ½ UL aging of EAS on engine dynamometer using defined cycles, followed by ½ UL aging of aftertreatment system using the Diesel Aftertreatment Accelerated Aging Cycle (DAAAC) protocol. This option would only be applicable for heavy heavy-duty diesel (HHDD) engines and would require periodic NOx sensor reporting (see Appendix 3 for further detail). 3) Full UL aging of EAS using accelerated aging protocols under development jointly by CARB, U.S. EPA and EMA. This option would require periodic NOx sensor reporting.
Averaging, Banking and Trading Credits	1) Termination of all pre-2010 MY generated credits 2) Expiration of post-2010 MY credits after 5 years 3) Potential establishment of California-only credit bank

[14] Staff evaluated various candidate LLCs and are considering using LLC candidate #7 as a certification cycle. For a discussion of the LLC development, please refer to Appendix 4, Heavy-Duty Low NOx Program Workshop - Low Load Cycle Development Presentation. January 23, 2019 (https://www.arb.ca.gov/msprog/hdlownox/hdlownox.htm) (See Appendix 4 for slides)

Table 3 – CARB Staff Assessment of Feasible Standards and Requirements for MYs 2027 and later

2027 and Subsequent MY Engines Assessment (Heavy-Duty and Medium-Duty Engines for > 10,000 pounds GVWR)	
NOx standards	-0.0x g/bhp-hr NOx on the FTP and RMC-SET -FTP, RMC-SET, LLC, and Idling standards to be determined based in part on results from SwRI Stage 3 Low NOx Demonstration program.[15]
PM standards	0.005 g/bhp-hr PM on the composite FTP and RMC-SET
HDIUT	1) Compliance based on modified Euro VI(E) method (See Appendix 1a) - Conformity factor: 1.5 - In-use threshold: 1.5 x FTP Standard - Power threshold: down to idle - Include cold start emissions in the compliance determination - Regular customer route - Pre-approval of test plan: operation type, location, etc. - Manufacturer could invalidate test day if over 50% of windows are below 10% of engine's peak power. Retest until a valid test day is completed 2) Possible alternate compliance option based upon completion of a successful pilot program using NOx sensor data such as those collected using REAL or other metrics (depending on NOx sensor technology development)
Durability Demonstration Program	Possible initiation of an alternate durability program upon successful completion of the 2024-2026 MY pilot program. Program could rely on NOx sensor reporting combined with some dynamometer aging and/or accelerated aftertreatment aging.
Averaging, Banking and Trading Credits	Continuing the MY 2024-2026 program
Useful Life & Warranty	For all engine classes: - Lengthen useful life and Warranty (Step 2) (specific lengths to be determined)

[15] 0.0x indicates that the staff is still evaluating the appropriate level of the standard, i.e., the x in 0.0x is still to be determined.

IV. Data and Sources Used in CARB Staff Assessment

In October 2015, CARB released technology assessment reports[16] that discussed the various engine calibration and aftertreatment strategies that could be employed to significantly reduce NOx emissions from heavy-duty engines. One assessment found that emissions from heavy-duty diesel engines can be significantly reduced utilizing a systems approach combining advanced aftertreatment systems with engine management strategies. For diesel engines, the report concluded that an engine meeting an optional NOx standard of 0.10 g/bhp-hr on the FTP could likely be certified within a year or two of the release of the document. This conclusion was based on (1) an assessment by one engine manufacturer that stated a 0.1 g/bhp-hr NOx standard on the FTP can be achieved with improvements to the current selective catalytic reduction (SCR) system, and (2) the low certification levels of some late model engine families. However, the report also concluded that reducing NOx further to the 0.02-0.05 g/bhp-hr levels and simultaneously reducing GHG emissions would require more development time and significant improvements in engine combustion efficiency, thermal management strategies, and advanced aftertreatment technologies.

As mentioned above, CARB is currently funding research projects with SwRI to demonstrate feasibility of low NOx emissions from on-road heavy-duty engines. There are three main stages of the SwRI low NOx research program referred to as Stages 1, 2 and 3 and 2 supplemental contracts referred to as SwRI Stages 1b and 3b. A Program Advisory Group representing engine manufacturers, aftertreatment suppliers, together with local and national regulatory agencies has been formed to consult SwRI at critical decision points including selecting aging protocols, hardware configurations, and low load challenge conditions.

The Stage 1 project[17] involved development work on both a 2012 MY 12-liter Cummins natural gas engine and 2014 MY 13-liter Volvo diesel engine with a target NOx emission rate of 0.02 g/bhp-hr on the FTP and RMC-SET test cycles. The Stage 1 project was a $1.6 million project funded by CARB with support from MECA, SwRI, and Volvo, which was completed in April 2017. This development work achieved a 0.01 g/bhp-hr NOx over the FTP and a 0.001 g/bhp-hr NOx level over the RMC-SET on the Cummins natural gas engine. Several natural gas and propane engines from 6 to 12 liters are currently commercially available meeting the CARB Optional Low NOx standard of 0.02 g/bhp-hr. In addition, the Volvo diesel engine achieved a 0.034 g/bhp-hr NOx level over the FTP and a 0.038 g/bhp-hr NOx level over the RMC-SET (the baseline NOx levels were 0.14 g/bhp-hr on the FTP and 0.08 g/bhp-hr on the RMC-SET). These results were achieved on full useful life aged advanced aftertreatment systems. The results for the diesel engine did not achieve the target NOx emission rate of 0.02 g/bhp-

[16] (1) CARB, Draft Technology Assessment: Lower NOx Heavy-Duty Diesel Engines, September 29, 2015
(2) CARB, Draft Technology Assessment: Low Emission Natural Gas and Other Alternative Fuel Heavy-Duty Engines, September 29, 2015. (https://ww2.arb.ca.gov/resources/documents/technology-and-fuels-assessments)

[17] Sharp, C.A., Webb, C.C., Neely, G.D, Smith, I., "Evaluating Technologies and Methods to Lower Nitrogen Oxide Emissions from Heavy-Duty Vehicles", Southwest Research Institute (SwRI) Project No. 19503 Final Report (2017). (https://www.arb.ca.gov/research/single-project.php?row_id=65182)

hr. However, the results were encouraging because despite this engine having a very challenging turbocompounding system which greatly cooled the exhaust and hence made NOx control harder, and despite a mechanical failure of the metal housing surrounding the catalyst substrate and the supporting mat (i.e., a canning failure) during the full useful life (435,000 miles) aging procedures, emissions were significantly reduced. The failure could have been prevented by a properly designed catalyst housing system. Overall, carbon dioxide (CO_2) emissions over the FTP test cycle increased by about 2.5 percent and over the RMC-SET by about 1.6 percent. The optimized EAS was also tested on vocational cycles such as the New York Bus Cycle (NYBC), the Cruise-Creep Cycle, and the Orange County Bus cycle (OCTA). Even though the diesel aftertreatment system was not optimized on these vocational test cycles, tailpipe emissions were significantly reduced due to the engine optimization on the FTP and RMC-SET with the advanced aftertreatment systems. Compared to baseline emissions testing, NOx emissions were reduced by 66 percent on the NYBC and by 52 percent on the OCTA cycle. CO_2 emissions were reduced by about 2 percent on the NYBC while on the OCTA cycle CO_2 emissions increased by 2.6 percent.

In addition to NOx emissions, Stage 1 also measured other criteria pollutant emissions to assess how these pollutants were impacted due to low NOx optimization/calibration and the selected advanced aftertreatment systems. Specifically, on the Volvo diesel engine, PM emissions levels remained low for the baseline engine system as well as the optimized EAS. Baseline emissions were 0.001 g/bhp-hr on the FTP and 0.002 g/bhp-hr on the RMC-SET. For the optimized engine with the advanced aftertreatment system, PM emissions were about 0.0007 g/bhp-hr on the FTP and 0.0002 g/bhp-hr on the RMC-SET.

The abnormal canning failure of the diesel engine aftertreatment system led CARB and other stakeholders to launch the Stage 1b project, currently in progress. It involves aging of a second set of identical Stage 1 aftertreatment components in order to assess the impact of the canning failure and to determine the effect of normal degradation on the aftertreatment system. Stage 1b is a $480,000 project funded by SCAQMD with support from MECA.

The Stage 2 project involves the development of a new LLC, which also involves further optimization of the Stage 1b diesel engine and aftertreatment system on vocational cycles and the developed LLC. This is needed because emissions from modern diesel engines are significant at low load operations. As shown in Figure 2, although vehicle miles traveled at low speed (and hence low load) represent less than 10 percent of the miles traveled, the NOx emissions from such operation are expected to constitute half of all emissions by 2030. This is because current SCR systems are inactive at low loads and low exhaust temperatures. Also, SwRI will benchmark the accuracy of estimated power information from late model diesel engines and evaluate other load measurement metrics for improving the in-use testing methods for determining emissions accuracy at low engine power conditions. Development of candidate LLCs has been completed and released for stakeholder feedback. Final LLC selection, system optimization, and development of low load measurement metrics are currently in progress. The project is

expected to be finalized by late April 2019. Stage 2 is a $1.05 million project funded by CARB with support from Volvo and MECA.

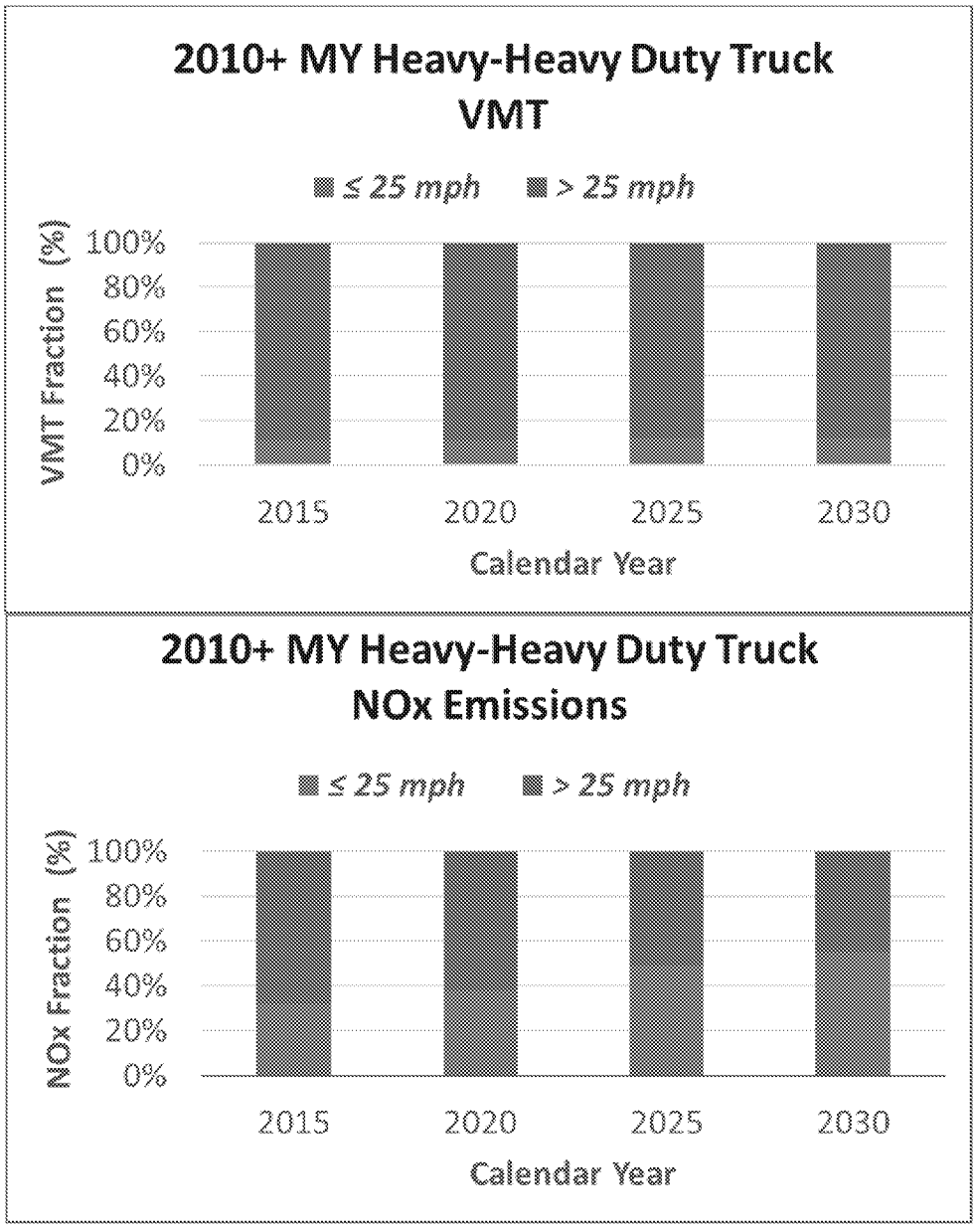


Figure 2 - NOx emissions from low-speed operation to become increasingly significant, due to SCR inefficiency at low loads[18]

Stage 3 involves evaluation of a more recent 2017 MY 15-liter Cummins diesel engine by optimizing/calibrating the engine and advanced emissions aftertreatment systems. The objective is to demonstrate low NOx technologies to achieve a target NOx emission

[18] Seungju Yoon et al., High In-Use NOx Emissions from Heavy-Duty Diesel Trucks Equipped with SCR Systems and Their Impact on Air Quality Planning in California. TRB paper #17-02027.

rate of 0.02 g/bhp-hr NOx on the FTP and RMC-SET, with simultaneous optimization of an EAS on vocational cycles and the selected LLC candidate developed in Stage 2. Stage 3 is a $1.375 million project funded by CARB, SCAQMD, and the Port of Los Angeles, with support from Cummins Incorporated and MECA.

Stage 3b is a $750,000 project funded by U.S. EPA, MECA, and the Clean High-Efficiency Diesel Engine VII) Consortium (which is managed by SwRI). It is a supplement to Stage 3, and it involves adding engine hardware technologies designed to reduce GHG emissions and improve the performance capabilities of advanced aftertreatment systems when engines operate under sustained low loads. Engine hardware to be investigated include cylinder deactivation, charge air cooler bypass, exhaust gas recirculation (EGR) cooler bypass, turbocharger bypass, and exhaust manifold insulation. Stages 3 and 3b are expected to be finalized in the 4th quarter of 2019.

Staff also looked at emission certification levels of current CARB certified heavy-duty engines. As shown in Figures 3 to 5 below, PM certification levels for the majority of heavy-duty diesel engines are below 0.005 g/bhp-hr on the FTP and RMC-SET. A small percentage of the light heavy-duty diesel and some natural gas engines, however, have PM certification levels between 0.005 and 0.01 g/bhp-hr on the FTP and RMC-SET.

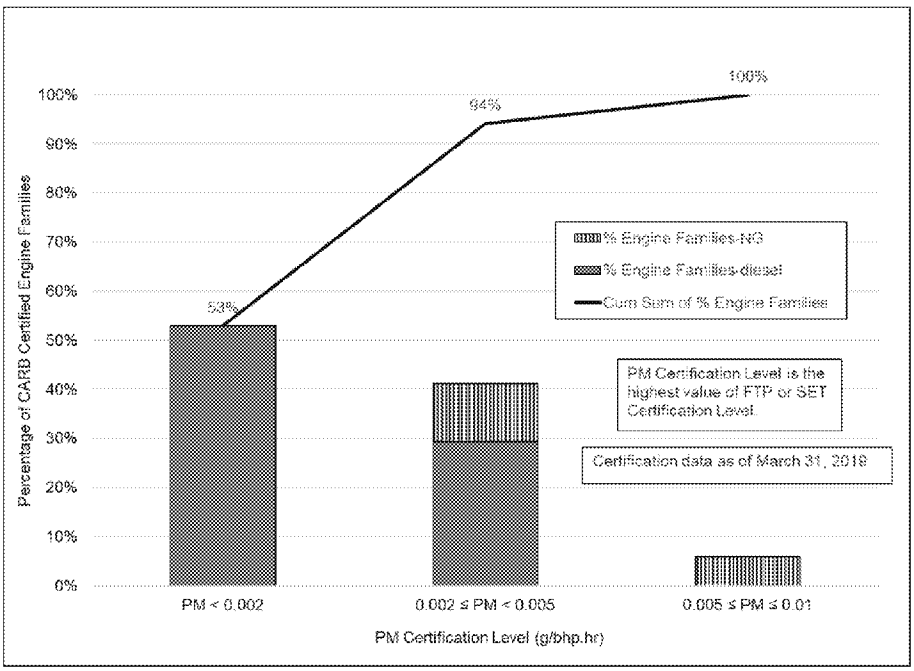


Figure 3 - PM emission certification levels for CARB certified 2019 MY heavy heavy-duty engines (GVWR > 33,000 pounds)

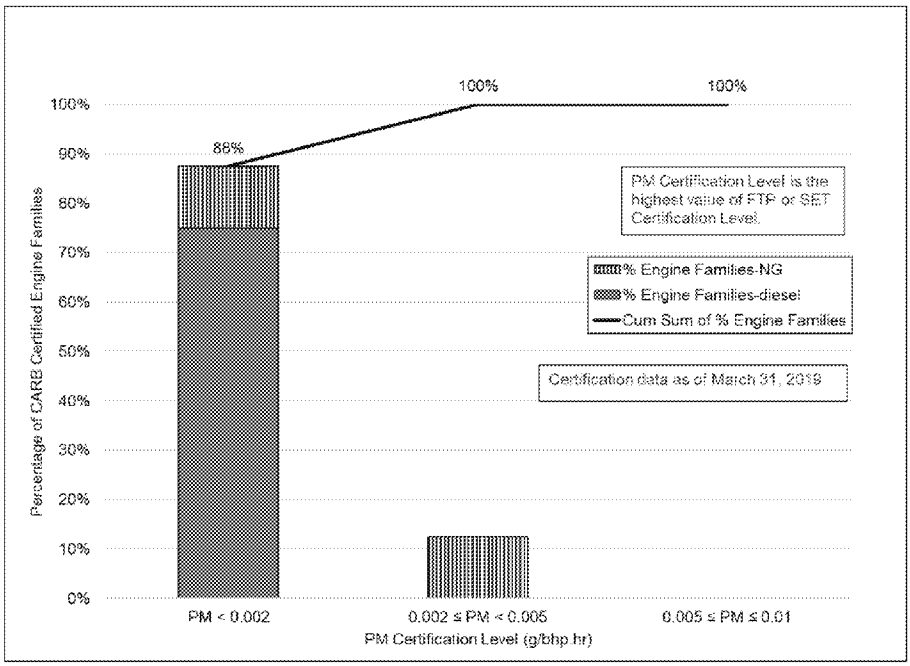


Figure 4 - PM emission certification levels for CARB certified 2019 MY medium heavy-duty engines (GVWR: 19,501-33,000 pounds)

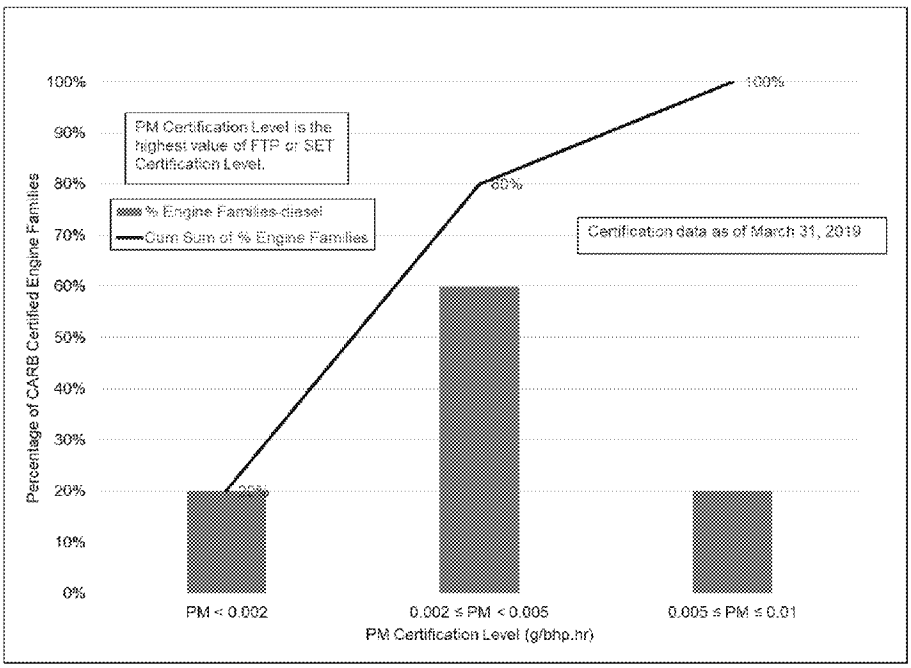


Figure 5 - PM emission certification levels for CARB certified 2019 MY light heavy-duty engines (GVWR: 14,001-19,500 pounds)

Similarly, Figures 6 through 8 show NOx emissions certification levels for current CARB certified heavy-duty engines. The charts show that many engine families have certification levels below 0.1 g/bhp-hr NOx with associated CO_2 emission levels below the 2027 MY Phase 2 GHG standards. Some of the heavy heavy and many of the medium and light heavy-duty engines have NOx certification levels close to the

certification standard with associated CO_2 certification levels higher than the 2024 MY Phase 2 GHG standards, indicating the need for more development work to reduce both NOx and GHG emissions simultaneously.

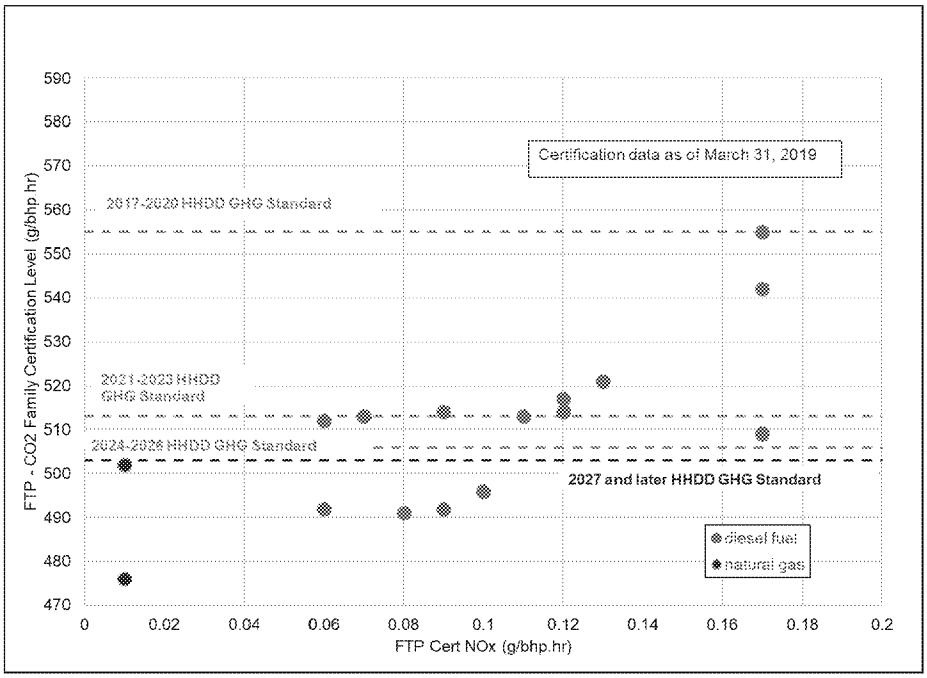


Figure 6 - Emission certification levels for CARB certified 2019 MY heavy heavy-duty engines (GVWR > 33,000 pounds)

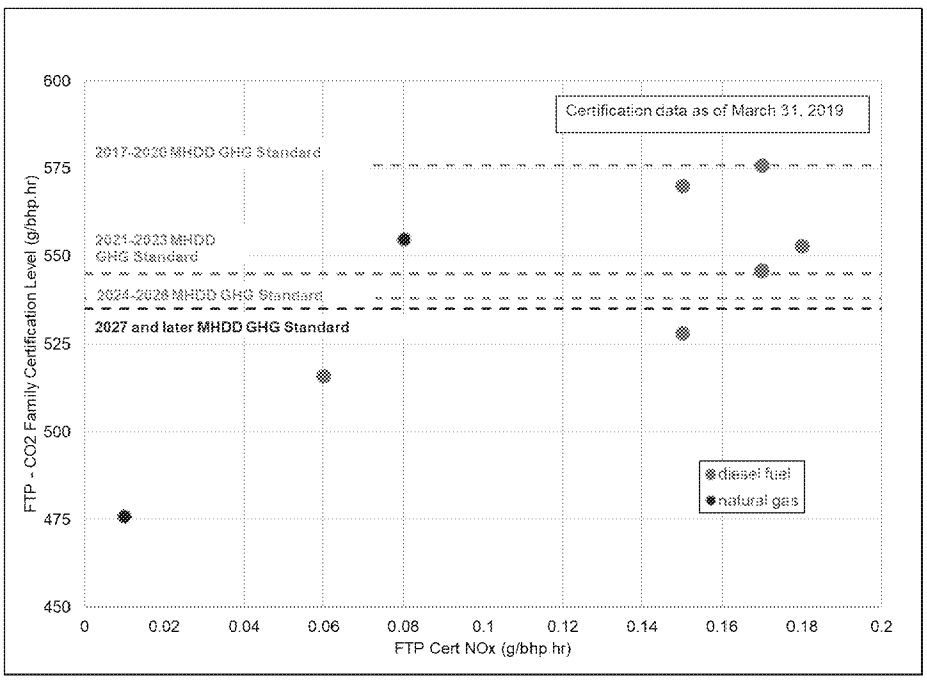


Figure 7 - Emission certification levels for CARB certified 2019 MY medium –heavy-duty engines (GVWR 19,501 to 33,000 pounds)

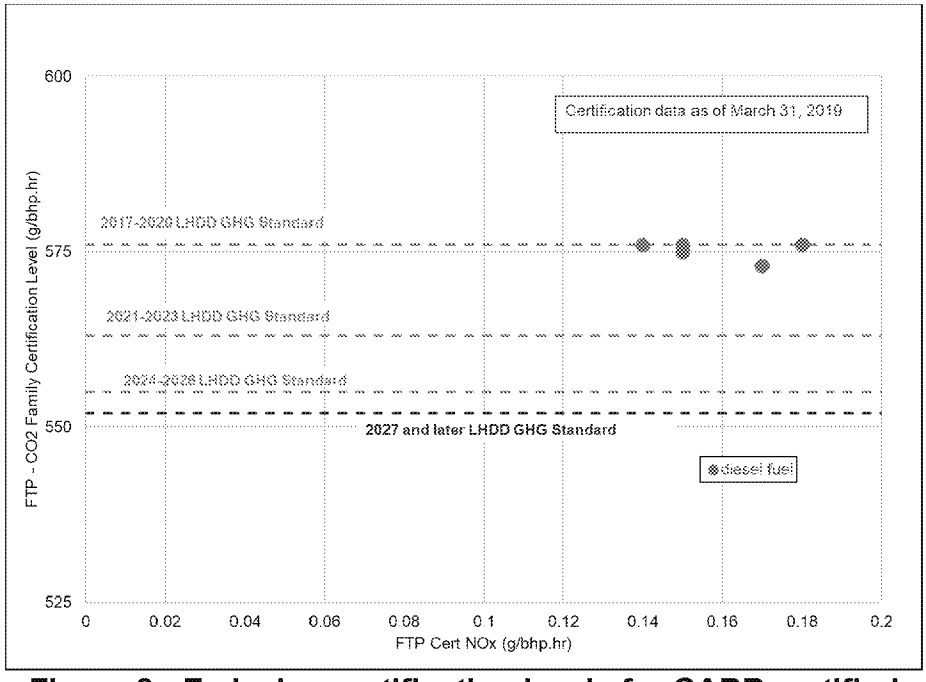
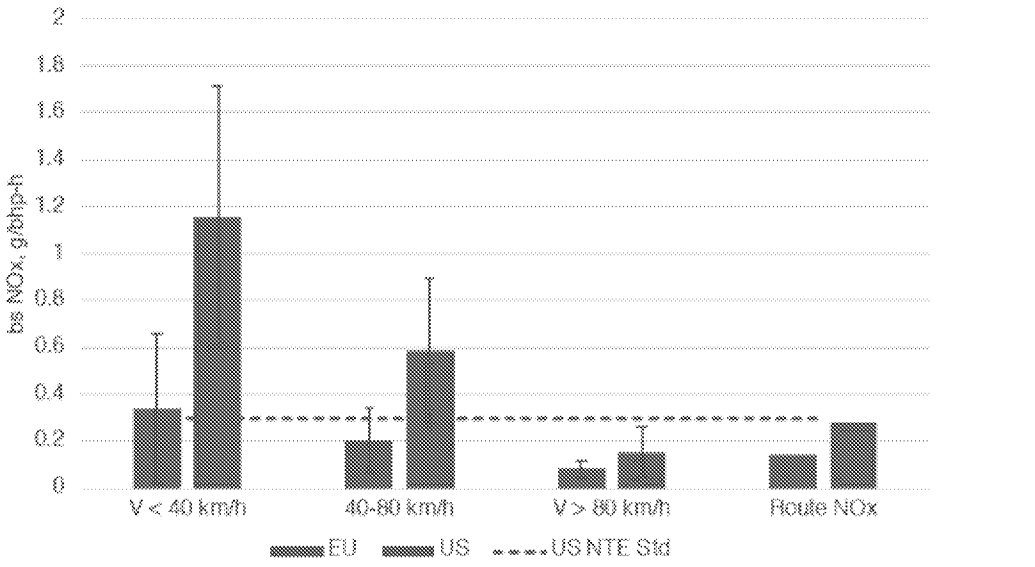


Figure 8 - Emission certification levels for CARB certified 2019 MY light heavy-duty engines (GVWR 14,001 to 19,500 pounds)

Staff also looked into an in-use data analysis performed by the International Council on Clean Transportation.[19] The analysis used emissions data from both the United States (U.S.) and European trucks to compare their in-use performance when evaluated using the U.S. NTE methodology and the European MAW based Euro VI methodology, respectively (Figure 9). It is important to note that the U.S. heavy-duty transient (FTP-based) certification NOx standard is significantly more stringent than the Euro VI standards. However, as shown in Figure 9 below, the analysis found that average brake-specific NOx emissions for U.S. trucks are about 3 to 4 times higher than European trucks, on average, indicating that European trucks are better in controlling emissions under most driving conditions. This is because Euro VI in-service conformity requirements force better calibration over the full duty cycle compared to the U.S. NTE methodology. In addition, the analysis found that there was a significant gap in emissions performance between European and U.S trucks at lower speeds in particular, further demonstrating the need to revise the current U.S. NTE methodology.

[19] Posada, Francisco, R. Muncrief, Preliminary results: A comparison of Real World Urban NOx Emissions measured with PEMS from HDVs in the US and the EU. August 2018 (CARB HDV In-Use testing workgroup meeting)



Duty cycles were not the same for EU and US trucks. Idling data was not included in this analysis. Comparison of 8 US 2010 HDVs and 8 Euro VI HDVs.

Figure 9 - Comparison between high selling U.S. vs EU heavy-duty engines: Large NOx emissions gap in more urban driving (Courtesy of ICCT – August 2018)

V. What requirements are feasible for 2022 and 2023 MY engines?

Staff believes the following improvements to the NTE protocol are technically feasible for 2022 and 2023 MY engines:

1. Changes to the current NTE method for MYs 2022 and 2023:
   Staff is considering changes to the existing NTE data exclusion protocol. Staff has identified the need to revise intake manifold temperature and the aftertreatment exhaust temperature exclusions based on technology improvements, including NOx control technologies implemented on 2010 and later MY engines that were not present during the NTE implementation phase in 2005 through 2009.

   The cold temperature exclusions relating to intake manifold temperature outlined in the 40 CFR 86.1370(f) to protect the EGR system from sulfur contamination and deterioration at low temperatures are antiquated and unnecessary for engines using ultra low sulfur diesel fuel, which is now universally available throughout the U.S. Engine manufacturers are currently using EGR during low temperature operation thereby demonstrating the intake manifold temperature exclusions are unnecessary. A minimum ambient temperature operation used in the Euro VI In-Service Conformity testing at 7°C will provide sufficient buffer from condensation within the EGR at cold temperatures.

The exhaust temperature exclusion for engines equipped with SCR (40 CFR 86.1370(g)) was initially set at 250°C due to catalyst activation and efficiency limitations. Advances in SCR aftertreatment catalysts have widened the operating temperatures available for NOx control. SCR catalyst efficiencies have been observed to have increased to 90 percent or more at temperature ranges down to 200°C (versus only 70 percent efficient just six years ago).[20] As a result, staff believes modifying the aftertreatment exhaust temperature exclusion cut point from the current 250°C to 200°C for MYs 2022 and 2023 is clearly technically feasible.

In addition, staff plans to propose a requirement that, beginning in 2022; manufacturers would need to provide a compliance report, in addition to providing an NTE compliance report, similar to what is required by Euro VI(D) requirements. The early reporting of the Euro VI(D) parameters would enable staff and manufacturers to assess how 2022 and 2023 MY engines are performing based on the Euro VI(D) methodology that would take effect starting with 2024 MY engines.

2. Changes to the Durability Demonstration Procedures:
   Currently, aging of the engine and aftertreatment system is performed at 35 to 50 percent of full useful life on an engine dynamometer. Deteriorated full useful life emissions are then estimated by linear extrapolation of emissions data. This method is inadequate since it does not address real life component failures and emission deterioration of engine-aftertreatment systems. To strengthen this procedure, certification staff intends to work with individual manufacturers on a case-by-case basis to devise mechanisms that would better verify product durability and deterioration factors for 2020 to 2023 MY engines.

3. Emission Warranty Information Reporting (EWIR):
   Staff plans to revise the EWIR requirements as discussed in the January 23, 2019 workshop for implementation in 2022 and later MY engines. The changes involve clarifying language on the consequences for not addressing in-use warranty issues in an expeditious manner (already allowed by statute). (See Table 1 above)

VI. What requirements are feasible for 2024 through 2026 MY engines?

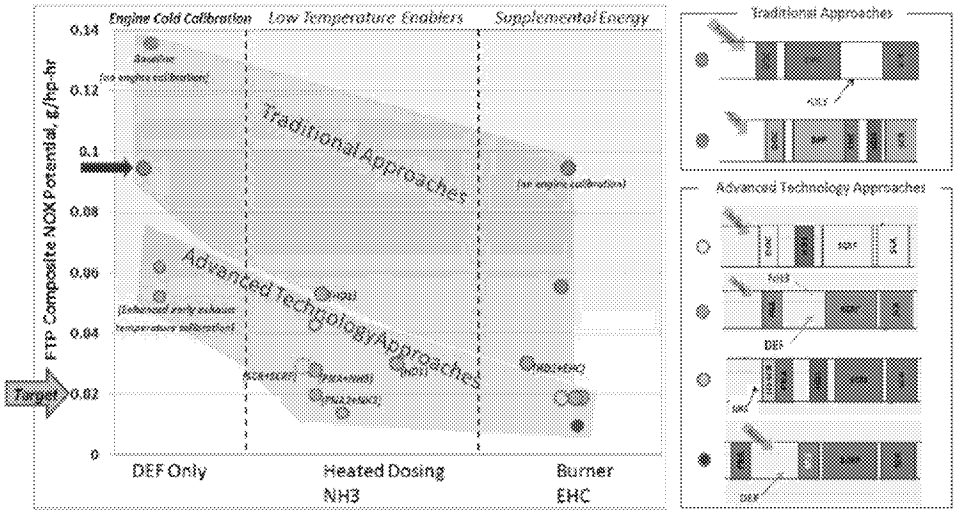
The following is staff's assessment on the feasibility of lower NOx standards for 2024 through 2026 MY engines based on information that is currently available to staff. Staff believes the changes discussed below are feasible without major engine and aftertreatment hardware changes such as cylinder deactivation, SCR coated on filter, passive NOx adsorber, and close-coupled light-off catalysts.

[20] (1) Newman, A. High Performance Heavy-Duty Catalysts for Global Challenges beyond 2020. Presentation at the 2018 SAE Heavy-Duty Diesel Emissions Control Symposium. October 17, 2018

A. NOx Emission Standard on Regulatory Cycles

Staff believes a NOx standard of 0.05 to 0.08 g/bhp-hr on the FTP and the RMC-SET is feasible for the 2024 through 2026 MY production.[21] As mentioned above, staff believes achieving this standard is feasible without significant hardware architecture changes. This assessment is based on the following information:

1. *Stage 1 Low NOx Project*: In this program, SwRI used engine calibration methods to increase exhaust temperatures and reduce engine-out NOx emissions in the cold start FTP. Calibration strategies used to achieve this objective were increased idle speed, double post injection, and increased EGR rates. Tests on the cold start and hot start FTP with the modified calibration and the stock aftertreatment system of the engine resulted in a FTP composite NOx level of less than 0.1 g/bhp-hr, as shown by the red arrow in Figure 10.[22] The corresponding GHG penalty was about 0.4 percent. No other strategies, such as EGR cooler or turbo bypass, were employed. Although the Stage 1 results are above 0.08 g/bhp-hr NOx, they nevertheless indicate that improved calibration can significantly reduce emissions and that further reductions are possible using improved thermal management and aftertreatment strategies during cold starts and low temperature operations, together with maintaining tight control thereafter.



Acronyms
DOC: diesel oxidation catalyst **DPF**: diesel particulate filter **SCR**: selective catalytic reduction **DEF**: diesel exhaust fluid
EHC: electrically heated catalyst **HD1**: heated DEF dosing **SCRF**: SCR catalyst coated DPF **PNA**: passive NOx adsorber
PNA2: PNA with altered catalyst formulation **NH3**: gaseous ammonia injection **LO-SCR**: close-coupled light-off SCR

Figure 10 Stage 1 Diesel Aftertreatment Screening Test Results

[21] The HD engine certification standards are also utilized by a subset of medium-duty vehicles (MDVs) in the 8,500 to 14,000 lb GVWR range. To avoid a disparity in NOx stringency for MDVs, staff plans to assess and take steps necessary to ensure similar robustness in emission control stringency for chassis certified MDVs in a similar timeframe to the HD engine standards.

[22] Sharp, C.A., Webb, C.C., Neely, G.D, Smith, I., "Evaluating Technologies and Methods to Lower Nitrogen Oxide Emissions from Heavy-Duty Vehicles", Southwest Research Institute (SwRI) Project No. 19503 Final Report (2017). (https://www.arb.ca.gov/research/single-project.php?row_id=65182).

2. *Certification levels of CARB certified 2019 MY heavy-duty engines*: As discussed above, Figures 6 through 8 show NOx versus CO_2 certification levels for 2019 MY CARB certified heavy-duty engines. As shown in Figure 6, more than 50 percent of the heavy heavy-duty engines are certified at or below 0.1 g/bhp-hr NOx. Many of these engines also exhibit CO_2 levels below the 2024 Phase 2 GHG standards (with some even below the 2027 Phase 2 GHG standards). This indicates that it is possible to meet the 2024 GHG emission standards and a NOx emission standard of 0.05 to 0.08 g/bhp-hr with current technology and some engine calibration changes to meet both standards. Note that most of the engines with NOx certification levels above 0.1 g/bhp-hr also have higher CO_2 emissions. These engines would likely need improved engine calibration and/or some engine/aftertreatment hardware changes to meet both 2024 GHG standards as well as a NOx standard of 0.05 to 0.08 g/bhp-hr.

   Staff acknowledges that some engine manufacturers certify well below the emission standard to provide a compliance margin. Again, as shown in Figure 6, some of the engine families are certified well below 0.08 g/bhp-hr NOx indicating the feasibility of certifying engines with a compliance margin.

   Figure 7 shows emission certification levels for NOx and CO_2 for 2019 MY medium heavy-duty engines. Two of the diesel engines already exhibit CO_2 levels below the 2027 Phase 2 GHG standards, with one engine already meeting a NOx certification level of 0.06 g/bhp-hr as well. Although other engines in this weight class are certified to higher NOx and CO_2 levels, this data point indicates that it is possible to meet the 2024 Phase 2 GHG standards and, at least, a 0.08 g/bhp-hr NOx level without significant changes to the engine and aftertreatment system.

   Figure 8 shows CO_2 versus NOx certification levels for 2019 MY light heavy-duty engines. For these engines emission certification levels are close to the current certification standards for both NOx and GHG. These engines indicate they would need some redesign of the engine aftertreatment system to meet the 2024 Phase 2 GHG standards. Optimization to achieve the 0.05 to 0.08 g/bhp-hr NOx emission levels could also be performed at the same time.

B. Particulate Matter Standards

As shown in Figures 3 to 5 above, most engines currently have PM certification levels well below the current 0.01 g/bhp-hr standard and certify close to 0.001 g/bhp-hr. However, over the last few model years some manufacturers have elected to certify some of their engine families to higher PM emission levels as a result of changes to the diesel particulate filter (DPF) substrate. During a meeting with one of the aftertreatment suppliers, it was confirmed that some engine manufacturers are selecting more porous DPFs to reduce engine backpressure at the expense of higher PM emission rates, albeit still compliant with the current PM standard. Thus, to maintain current robust PM emission control performance at 0.001 g/bhp-hr levels, staff is considering a lower PM standard of 0.005 g/bhp-hr. This change is feasible with existing DPF aftertreatment

systems and would assure that the best DPF technologies continue to be utilized for the maximum control of PM emissions.

C. NOx Emission Standard on Low Load Cycle

As described above, two of the tasks of the Stage 2 project are the development of the LLC and optimization of the EAS on this cycle. The development of candidate LLCs and baseline testing on the LLCs has been completed. Baseline tailpipe NOx emissions on the preferred LLC for two engines were 0.8 g/bhp-hr and 1.5 g/bhp-hr[23] while the corresponding engine-out emissions were 3.2 g/bhp-hr and 4.2 g/bhp-hr. Since both engines have similar SCR systems, staff believes the large difference in emissions between the two engines is primarily due to differences in engine-out emissions and system calibration.

Assuming a NOx baseline of 0.8 g/bhp-hr NOx on the LLC (as already demonstrated with today's technology), staff believes NOx emissions can further be reduced through engine calibration changes aimed at reducing engine-out NOx and increasing exhaust temperatures. Marginal exhaust temperature profile improvements can make significant differences by allowing urea dosing and SCR NOx conversion during an increased fraction of the duty cycle. Such NOx optimization strategies could be incorporated together with the changes to be made to meet the GHG standards in a single engineering effort. Staff believes a NOx standard of 1 to 3 times the proposed FTP standard is feasible on the LLC in 2024. As discussed above, SwRI has demonstrated in the Stage 1 project NOx reductions of about 50 percent on the OCTA cycle and 66 percent on the NYBC through engine calibrations that reduced engine-out emissions and increased exhaust gas temperatures. Staff does not plan to propose a CO_2 emission cap on the LLC for the 2024 through 2026 MY engines.

D. Heavy-Duty In-Use Testing

An assessment of the current HDIUT program using the NTE methodology shows that the vast majority of driving conditions is not evaluated and goes un-checked for in-use compliance.[24] This is due to the numerous exclusions incorporated in the NTE procedures,[25] including those for intake manifold temperature and aftertreatment exhaust temperature, the NTE control area, and the requirement for a continuous 30-second operation for a valid NTE event. The limitations and inadequacies of the current NTE methodology has compelled staff to pursue a MAW approach similar to the method used currently in Europe (Euro VI(D)).[26] Euro VI(D) does not have most of the data

[23] Heavy-Duty Low NOx Program Workshop - Low Load Cycle Development Presentation. January 23, 2019 (https://www.arb.ca.gov/msprog/hdlownox/hdlownox.htm) (See Appendix 4 for slides)

[24] Bartolome, C., et al., 2018. "Toward Full Duty Cycle Control: In-Use Emissions Tools for Going Beyond the NTE", 28th CRC Real World Emissions Workshop, March 18-21, Garden Grove, CA

[25] 40 CFR § 86.1370 - Not-To-Exceed test procedures

[26] COMMISSION REGULATION (EU) No 582/2011, May 25, 2011 (https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02011R0582-20180118&from=EN) COMMISSION REGULATION (EU) 2018/932, June 29, 2018

exclusions included with the NTE method, enabling evaluation of a much greater fraction of collected in-use data. Figure 11 shows a comparison of the current NTE method, a possible version of an improved NTE method, and a modified Euro VI(D) method using the FTP rather than Europe's World Harmonized Test Cycle as the defined work window. The bar charts clearly show the superiority of the modified Euro VI(D) method in its ability to capture more of the test time and NOx emissions for evaluation compared to either of the NTE methods. Furthermore, staff will likely propose to use the same conformity factor and percentile pass criteria as used with Euro VI(D). For a passing test, Euro VI(D) requires the 90th percentile of windows be less than the in-use threshold, which is the product of the conformity factor and the FTP emission standard (1.5 x FTP Standard).

Staff is also considering an alternative compliance path using NOx sensor data collected using the On-Board Diagnostic's (OBD) REAL monitoring system. This option is contingent on NOx sensor technology development being able to monitor emissions at low NOx levels as well as monitor emissions over the whole duty cycle of heavy-duty vehicles operations. Manufacturers need to institute such a strategy under a pilot program before replacement of the manufacturer-run HDIUT program for the 2027 MY engines.

Unlike the Euro VI(D) that specifies the mix of route operation (rural, urban, highway), staff plans to propose that the vehicle be driven on its regular fleet route. Additionally, a manufacturer would have to submit the test plan, including but not limited to, test location, operation type (regional, line haul, etc.), and time of year testing will be conducted. Also, to ensure the results are not biased by fleets that happen to have an unusually high portion of low load operating conditions, staff plans to propose that a manufacturer may invalidate any test day with over 50 percent of windows at or below the 10 percent power threshold, the same as with Euro VI(D). However, manufacturers would need to continue to perform testing until they obtain valid testing results.

Staff believes implementation of the modified Euro VI(D) methodology with an in-use threshold of 1.5 x FTP standard for engine MYs 2024 through 2026 is technically feasible. Although engines certified in Europe today are complying with current Euro VI(D) requirements using aftertreatment technologies that are similar to those currently used in the U.S., these engines are meeting an in-use threshold that is over 4 to 7 times higher than the proposed CARB in-use threshold (0.51 g/bhp-hr in Europe versus 0.075 to 0.12 g/bhp-hr in U.S.). As a result, staff believes manufacturers will need to do additional calibration and potentially aftertreatment hardware improvements to meet the more stringent CARB in-use threshold. Staff understands that there are certain cycle conditions that arise from real world testing and absent in the prescribed cycle of Euro VI method to be challenging from an emissions control perspective. Technical assessment and provisions for these specific operations will be ongoing to ensure feasible compliance and control for the 2024 MAW implementation.

(https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018R0932&from=EN)

Another challenge is complying with the Phase 2 GHG standards while meeting the modified Euro VI(D) in-use threshold. In Europe, heavy-duty vehicle GHG standards have been developed but are not currently being implemented. Not faced with the constraint of GHG standards, European manufacturers have reported that compliance with the current Euro VI(D) in-use threshold results in an increase in CO_2 emissions during sustained low-load operation. As a result, staff believes U.S. manufacturers may need to do additional calibration and potentially change engine hardware to meet both the Phase 2 GHG standards and the modified Euro VI(D) requirements.

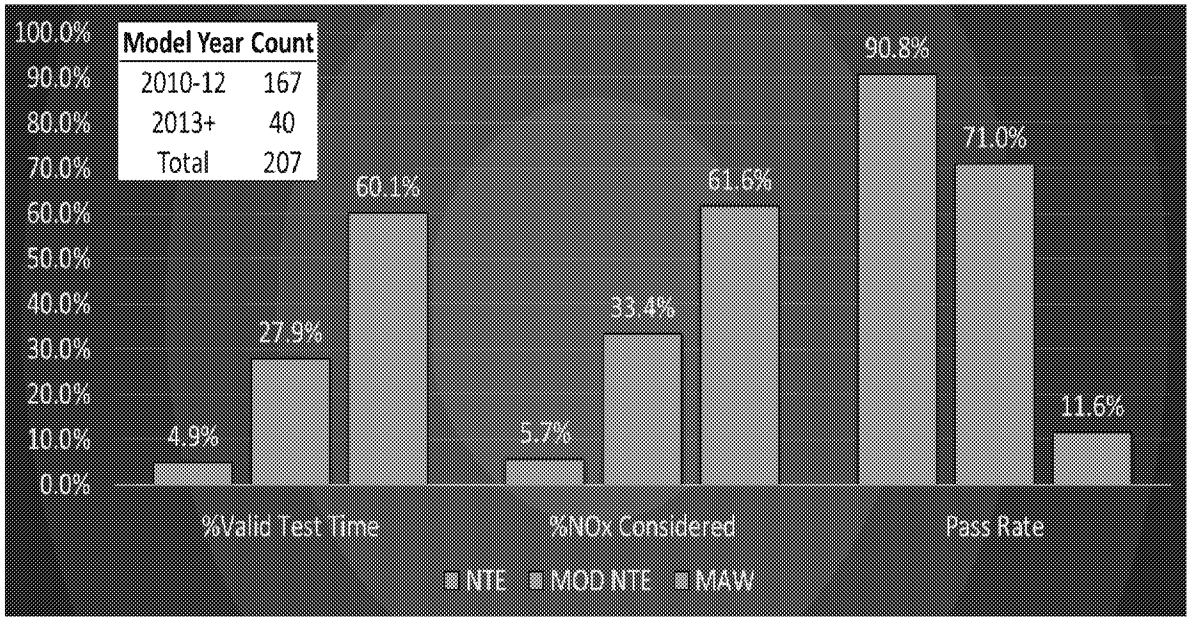


Figure 11 Method Comparison: MAW Captures More of Test Time and Emissions on HDIUT data set

E. Vehicle Technologies that Benefit NOx Emission Reductions

As discussed in previous workgroup meetings, staff also plans to recognize vehicle technologies that would provide NOx emission reductions over the engine certification cycles. Staff plans to work with manufacturers as well as with U.S EPA to develop a testing method for crediting these technologies. Such technologies may include stop-start systems, hybrid technologies, and others.

F. Changes to the Durability Demonstration Procedures:

Staff discussed potential revisions to the durability demonstration procedures for heavy-duty diesel engines in the January 23, 2019 workshop (see appendix 3). These changes would require the manufacturers to age the EAS to full useful life as part of the certification program.

Since the January 23, 2019 workshop, staff has also discussed other possibilities for durability demonstration with U.S. EPA. As a result, CARB staff is currently considering

providing manufacturers three options for demonstrating EAS durability for the 2024-2026 MY period. These options are described below:

1. Full UL aging of the EAS on an engine dynamometer using either standardized engine certification cycles (FTP, RMC-SET), or the engine cycles generated from the Phase 2 Greenhouse Gas Emission Model (GEM) using the worst case vehicle/engine combination (worst case would be the vehicle configuration that yields the highest cycle-average power level for each engine family). Manufacturers would need to determine the highest cycle-average power level for both FTP/SET or GEM scenario, and choose the scenario with the highest cycle-average power level. Details regarding the engine dynamometer pathway selection process, the required aging hours, and the sequence of aging cycles are shown in Appendix 3.

2. In the January 23, 2019 workshop, staff also presented an option for HHDD engines that would require aging the EAS for ½ UL on an engine dynamometer, followed by ½ UL aging of the aftertreatment system using the Develop an Accelerated Aging (DAAAC) Protocol. The engine dynamometer aging cycle would be determined similar to how it was determined in option 1. The intent of this option is to reduce the number of aging hours required for the durability program by introducing accelerated aging for a portion of the program. This option would require periodic submittal of NOx sensor data to CARB in order to validate the results from the DAAAC protocol.

3. Based on discussions between CARB and U.S. EPA, both agencies plan to jointly work with EMA to come up with an accelerated EAS aging protocol for all primary intended service classes of heavy-duty engines. Detailed information regarding the feasibility and the development timelines for this protocol is not available at this time, but staff is interested in development of an accelerated aging protocol that would represent real-life aging of the EAS. Since this option would focus on accelerated EAS aging, staff anticipates that periodic NOx sensor reporting would be a requirement under this option.

Although the durability demonstration proposal increases the cost and the length of the durability demonstration program to individual manufacturers from its current baseline values, staff believes that the new requirements are cost effective and would not cause major disruptions to the product development cycle. Staff has already performed a preliminary cost analysis and will include the additional costs due to the new durability requirements in the final program cost study.

In terms of additional aging hours and product development timelines, option 2 would require manufacturers to dedicate approximately 5,500 hours for the durability demonstration program. This is comparable to the 4,000-hour durability program that several off-road compression-ignition manufacturers are currently performing to satisfy CARB's durability requirements. Staff believes that a 5,500-hour durability program would take approximately one year to complete and would not adversely impact product development.

The requirement to submit NOx sensor data (using REAL or other metrics) by manufacturers would be instrumental in development of a new alternative durability program for the 2027 and subsequent MY products, when the useful life values are planned to be increased for all heavy-duty primary intended service classes.

G. Warranty and Useful Life Periods

In June 2018, CARB adopted amendments to the California on-road heavy-duty diesel vehicle and heavy-duty engine warranty regulations to lengthen existing warranty periods, allow maintenance provisions to better reflect the longevity and usage of modern vehicles, and explicitly link the heavy-duty OBD system to the definition of a warranted part. These amendments will be effective with the 2022 MY. However, these "Step 1" lengthened warranty periods, as well as the currently defined useful lives, still fall short of reflecting the real-world longevity of modern heavy-duty vehicles. Accordingly, staff intends to propose increased useful live and lengthened "Step 2" warranty period amendments, for these vehicles and engines, to be effective with the 2027 MY. Staff has no plans to revise the warranty and useful life periods for the 2024 through 2026 MY engines.

VII. Feasibility of Standards

A. Technologies for 2024-2026 MY Standards

Table 4 lists some of the technologies that may be employed to meet the 2024-2026 MY standards. These enabling technologies are either currently commercially available or planned to be implemented by some manufacturers in the next one to two years.

Table 4 – List of Technologies for the 2024 – 2026 MY Engine Standards

Engine calibration strategies	Increased EGR, post-injection, increased idle speed.
Aftertreatment system strategies	Increased catalyst size, improved SCR catalyst (high cell density and high porosity substrates), better urea injection control, heated dosing, and twin SCR systems in one box with dual dosing.
Engine hardware	EGR cooler bypass, turbo bypass, charge air cooler bypass.

The various engine hardware bypasses, split SCR systems, and heated dosing may be driven mainly by the need to meet the low load cycle standard, the in-use standards, and idling standard and not necessarily by the need to meet the FTP or RMC-SET standards.

Some of the above strategies may increase GHG emissions when incorporated in current engines, as was observed in the Stage 1 Low NOx program. However, since these engines are going to be re-designed and optimized to meet the 2024 GHG emission standards, NOx optimization strategies could also be incorporated together with the changes made to meet the GHG standards in a single engineering effort, minimizing GHG emissions impacts.

B. Technologies for 2027 and later MY Standards

Meeting the 2027 MY engine standards will require optimization of the 2024 MY technologies plus additional technologies such as those listed in Table 5.

Table 5 – List of Technologies for the 2027 and Later MY Engine Standards

Engine calibration strategies	2024 MY strategies plus optimization.
Aftertreatment system strategies	Further optimization of 2024 MY strategies plus advanced catalysts such as SCR coated on filter, twin SCR systems with light-off SCR close-coupled to the engine and dual dosing, better urea injection control, etc.
Engine hardware	2024 MY engine hardware strategies plus cylinder deactivation, stop-start systems, early exhaust valve opening, etc.

VII. Heavy-Duty Low NOx Implementation Timeline

Figure 12 below shows implementation phases of the various elements included in the Heavy-duty Low NOx Omnibus Rulemaking as well as implementation of the various phases of the Phase 2 GHG requirements. The implementation dates to meet the low NOx requirements discussed in this white paper have been designed to coincide with the implementation dates to meet the Phase 2 GHG standards. This would provide manufacturers the opportunity to implement NOx optimization strategies together with the changes to meet the MY 2024 and 2027 Phase 2 GHG standards.

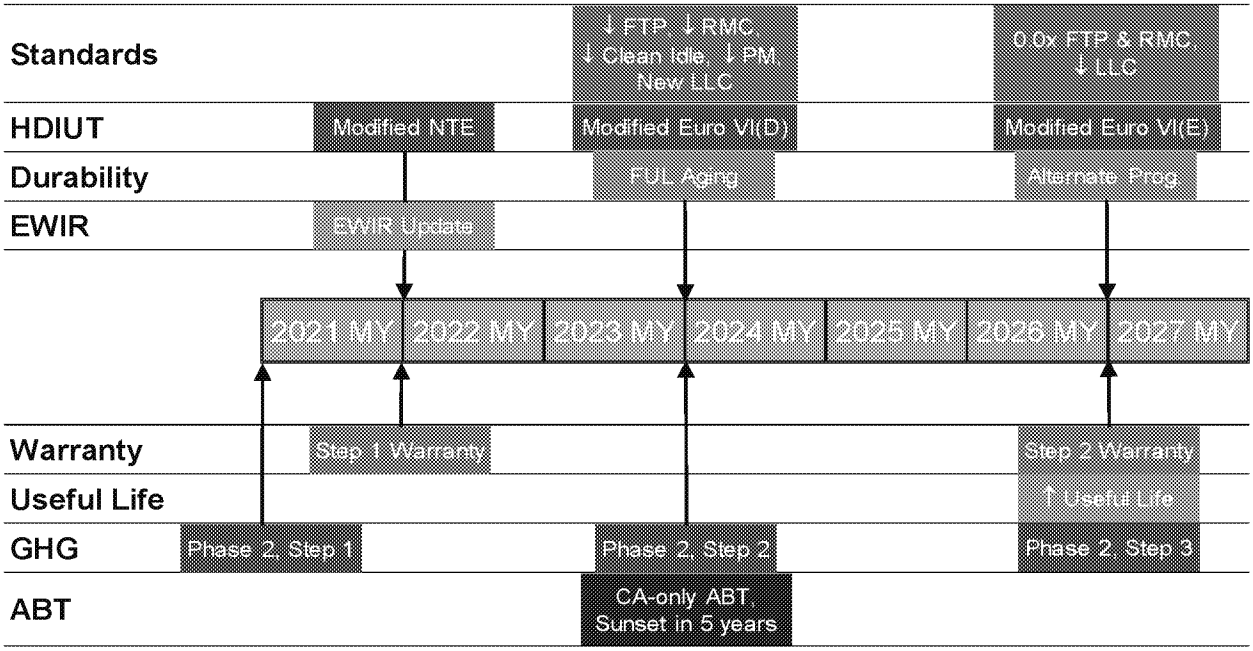


Figure 12 CARB Heavy-Duty Low NOx Rulemaking Implementation Timeline

VIII. What will the cost of compliance with the proposed requirements be?

Staff understands that manufacturers will incur costs to comply with the proposed requirements discussed above. Based on preliminary estimates, CARB staff believes that the MY 2024 provisions described in this white paper could be met at a cost effectiveness of less than $3/pound NOx. The $3/pound NOx estimate is well within the cost-effectiveness of previous rulemakings adopted by CARB.

CARB has contracted with the National Renewable Energy Laboratory (NREL) to help estimate compliance costs associated with the Heavy-Duty Low NOx program. NREL is currently in the process of collecting cost data; the results are expected to become available by May 2019. Once these results are available, staff plans to seek further input from industry and refine the cost-effectiveness assessment.

XI. Conclusions and Next Steps

It is staff's intent that this white paper will help provide clarity in addressing engine manufacturers' concerns and uncertainties with regard to lead time and potential regulatory requirements impacting their MY 2022 through 2026 products.

Staff plans to continue to engage the engine manufacturers, EMA, and other stakeholders to listen and address their concerns, and share any information that becomes available from the various research projects currently in progress. Staff will also continue to hold workgroup meetings and workshops to reach out to stakeholders, nongovernmental environmental organizations, trade associations, and the public.

Attachments

Appendix 1a – Heavy-Duty In-Use Testing (HDIUT) Presentation

Appendix 1b – Compliance report checklist for MAW Euro VI(D)

Appendix 2 – Emission Warranty Information Reporting (EWIR) Presentation

Appendix 3 – Durability Demonstration Program (DDP) Presentation

Appendix 4 – Low Load Cycle Development (LLC) Presentation

Appendix 1

CALIFORNIA AIR RESOURCES BOARD

HEAVY-DUTY LOW NO_x PROGRAM WORKSHOP

JANUARY 23, 2019

HEAVY-DUTY IN-USE TESTING (HDIUT)

MOBILE SOURCE CONTROL DIVISION

CALIFORNIA AIR RESOURCES BOARD

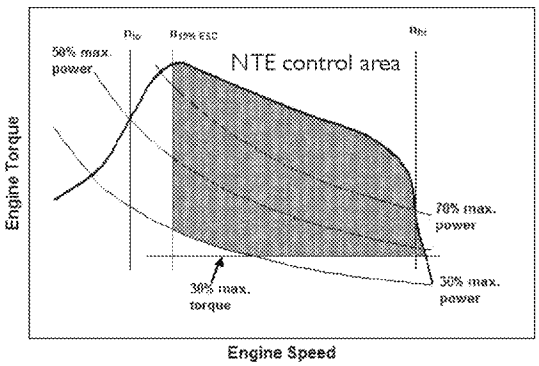
HDIUT: OUTLINE

- Current HDIUT / Not to Exceed (NTE) program
- Problems with current program
- Proposed changes
  - Administrative and Reporting
  - Testing Conditions and Exclusions
  - Full Duty Cycle Control
  - Moving Average Windows (MAW)
  - Pass Fail Determination

2

HDIUT: BACKGROUND

- 2003: Outline of the HDIUT developed by U.S. EPA, CARB, and Engine Manufacturer's Association
- 2005: EPA adopts Manufacturer Run HDIUT
- 2006: CARB adopts HDIUT and national HDIUT pilot year
- 2007: 1st year of HDIUT criteria pollutant enforcement



https://www.dieselnet.com/standards/cycles/images/nte.png

3

HDIUT: CURRENT REQUIREMENTS (40 CFR PART 86 SUBPART T)

	Current CARB & EPA HDIUT
Request for testing	• CARB & EPA Requested
Engine Selection	• 25% of engine families certified
Frequency	• Annually
Driver	• Regular Fleet Driver
Route	• Regular Fleet Route
Method	• Not-to-Exceed
Exclusions	• Ambient, 30% min power, 30% min torque, min-rpm, zero check, AT-temp, cold operations, intake manifold temperature (IMT), engine coolant temperature (ECT), On-Board Diagnostic (OBD) fault code, Engine Manufacturer Diagnostic fault codes, diesel particle filter (DPF) regeneration
Window Validity	• 30 sec continuous operation within NTE control area without entering exclusions operation
Emissions	• Brake specific [g/bhp-hr]
In Use Thresholds	• 1.5 x Std. + PEMS accuracy margin [0.45 g/bhp-hr NO_x threshold]
Pass Determination	• 90% of time weighted valid NTE events must emit at or less than the In Use Threshold

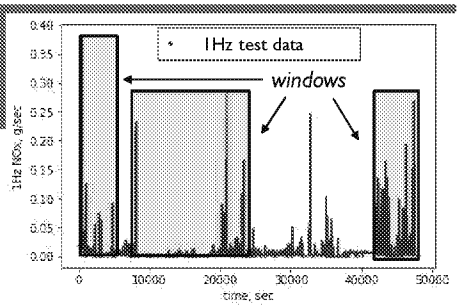
4

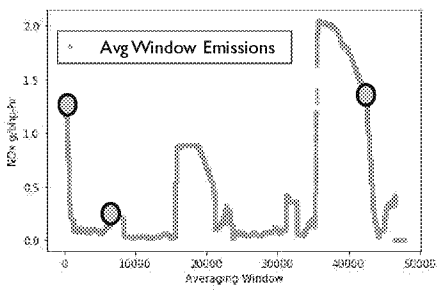
HDIUT: CURRENT ISSUES AND LIMITATIONS

1. Current HDIUT program targets sustained high speed and high load operation for gross NO_x polluting offenses
2. After applying the current exclusions, valid data from testing represents a small fraction of the total test in terms of time (<5%) and NO_x emissions (<6%)
3. 24% of tests pass without any valid NTE events
4. Current HDIUT does not represent the full duty cycle emissions
5. There is a discrepancy in the pass rates observed by the manufacturer (91%) and CARB-run HDIUT(44%) results. (CARB testing: 20 of 36 failed NTE)

MOVING AVERAGE WINDOWS (MAW)

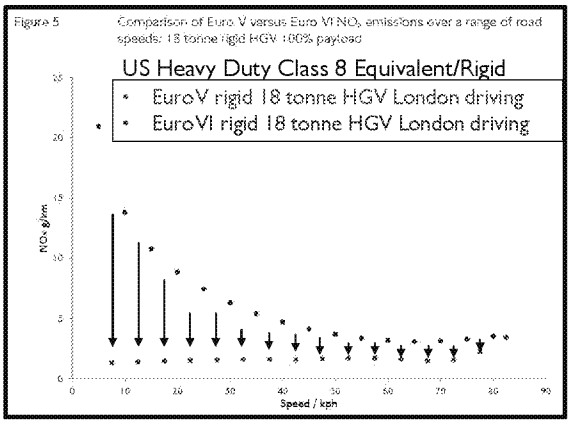
- Implemented in Euro VI regulations for In-Use Conformity testing
  - Mass emissions are calculated for subsets, i.e., "windows", of complete data set.
  - Length of windows based on the reference work or CO2 measured over the transient certification cycle [Ref Cycles: WHTC in Europe and FTP in USA]
  - Windows are started at every second of the data set given that there is enough following data to complete a window length
  - 1Hz NOx emissions are averaged over a window (highlighted in grey).
  - Window emissions are reduced to a single point Window Average.
  - The averaged window emissions are ordered and the 90th percentile window is compared with the emission standard
  - The ratio of the 90th percentile emission to the emissions standard must not be greater than the conformity factor, 1.5





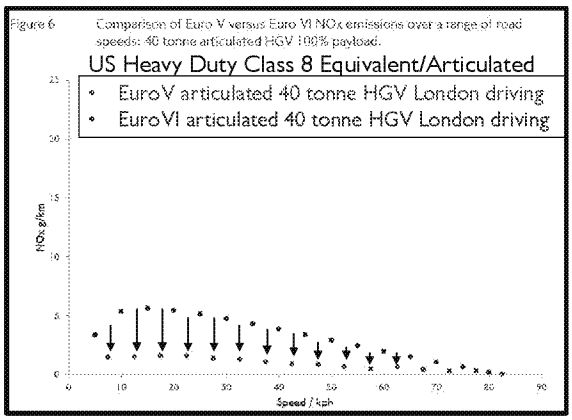
EMISSIONS BENEFITS IN LONDON FROM MAW IMPLEMENTATION

Figure 5 Comparison of Euro V versus Euro VI NO_x emissions over a range of road speeds: 18 tonne rigid HGV 100% payload



(2015) In-service emissions of Euro 6/VI vehicles. A summary of testing using London drive cycles. Transport for London.

Figure 6 Comparison of Euro V versus Euro VI NOx emissions over a range of road speeds: 40 tonne articulated HGV 100% payload.



(2015) In-service emissions of Euro 6/VI vehicles. A summary of testing using London drive cycles. Transport for London.

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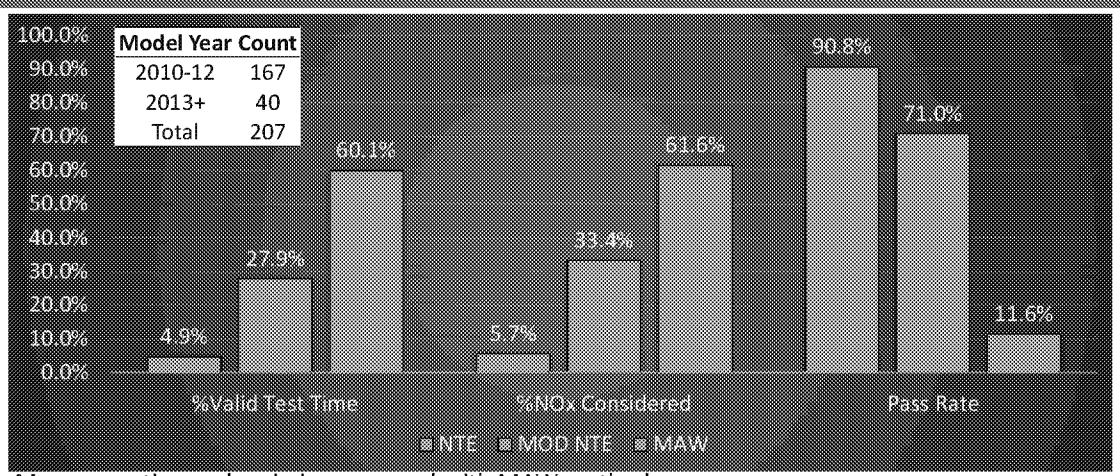
METHOD COMPARISON: MAW CAPTURES MORE OF TEST TIME AND EMISSIONS ON HDIUT DATA SET



- More operation and emissions covered with MAW method
- New method would improve real world emissions performance

8

CHANGES TO THE HDIUT PROGRAM

- **Remove the Following Elements:**
  - Discard the Not-to-Exceed method, NTE control area, operation exclusions, and averaging period
  - Discontinue the use of the PEMS accuracy margin allowance [0.15 g NO_x/bhp-hr]
- **Proposed Changes:**
  - Use the Euro VI MAW based method
  - Window size based on the test engine's work or CO_2 measured on the FTP cycle
  - Incorporate control over higher emitting windows: cold start, low load, idle operation
    - Weighted composite cold start and warm running emissions
- **Additional Reporting:**
  - CARB pre-approves manufacturer's HDIUT test plans
  - Data quality checklist assuring valid and complete test data was collected prior to submittal

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HDIUT: ENGINE FAMILY SELECTION AND TEST PLAN APPROVAL

- **Engine Selection**
  - CARB and EPA will continue to work together in selection of engine families for HDIUT
  - Rules for number of engine families selected annually and over a 4 year average would stay in place
- **Manufacturer test plan must be approved by CARB**
  - Test vehicle to be driven by fleet operator (manufacturer may also do testing with CARB/EPA approval)
  - Test vehicle to be driven over its regular fleet route (or CARB/EPA approved test route)
  - Season, ambient conditions, and other test conditions to be reviewed and require approval by CARB

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HDIUT: COLD START CRITERIA AND DATA EXCLUSIONS

- **Cold Start and Warm Up Conditions**
  - Cold start: engine must start with either:
    - Engine coolant must be less than or equal to 30 deg C
    - Engine coolant must be less than the ambient temperature by 2 deg C
  - Engine warm up must be within the first 15 min from engine start by satisfying either:
    - Engine coolant reaches 70 deg C for the first time
    - Engine coolant stabilizes within plus or minus 2 deg C for 5 minutes
- **Atmospheric Pressure and Temperature Range**
  - Ambient pressure and temperatures outside the current altitude, temperature, and pressure ranges shall be excluded from evaluation
- **PEMS QC Exclusions**
  - Data collected during the periodic instrument zero or drift checks excluded from evaluation

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HDIUT: MAW ANALYSIS METHOD

- **Moving Average Windows**
  - Subsets of continuous overlapping windows
  - Incremental averaging rate, 1Hz
  - Window size based on a reference Work or CO_2 mass on the FTP cycle
  - Size of windows shorter than the FTP are also being evaluated at SwRI
  - Window average power must be greater than the threshold power to be valid
    - Initially set power threshold to 10% maximum engine power [EuroVI(d)]
    - Future power threshold reduced to idle operation
- **Emission Metrics**
  - Average brake and CO_2 specific emissions of windows will be reported
  - Emissions at low loads and idle operation require a method other than brake specific emissions
  - CO_2 and fuel rate among other metrics are being evaluated by SwRI

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HDIUT: PROPOSED METHOD WITH PHASE IN TIMELINE

Model Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
HDIUT Methodology	NTE			Euro VI(d) MAW				Future method		

- 2022 to 2026 MY Engines
  - Based on Euro VI(d)
  - Deviations from Euro VI(d):
    - Real world fleet route and fleet driver
    - Reference window size based on FTP
    - Minimum of 3 hours of valid test data
- Potential changes for the future method (2027+ MY)
  - Weighted cold starts emission inclusion [similar to Euro VI(e)]
  - Expand operation down to idle
  - May have different window size
  - May introduce new emissions metrics

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HDIUT: COLD START EMISSIONS [EURO VI(E)]

1. **Calculate the conformity factor for all windows of the test**
   - *CF = [avg window emissions / emissions std]*
2. **Obtain CF_{cold} for the cold portion of the trip**
   - *CF_{cold} = highest CF window value for windows between:*
   - *Engine start and before $T_{engine\ coolant}$ reaches 70 °C*
3. **Obtain CF_{warm} for the warm portion of the trip**
   - *CF_{warm} = The 90th percentile window emissions for windows:*
   - *70 °C ≤ $T_{engine\ coolant}$*
4. **Weight results in following way**
   - The weighted summation of the cold and warm emissions shall not be greater than 1.5
   - Cold and warm start weighing factors will be similar to the composite FTP emissions
   - *$1.5 \geq [0.14\ (CF_{cold}) + 0.86\ (CF_{warm})]$*

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HDIUT: FUTURE METHOD SUMMARY

Key:
Previous Requirements
New or updated Elements

	MY 2022-2026	MY 2027+
Testing Request	• CARB & EPA	• CARB & EPA
Number of Families	• 25% EFs per year	• 25% EFs per year
Test Plan	◦ Mfr. Submitted for CARB approval	• Mfr. Submitted for CARB approval
Driver & Route	• Real world fleet driver and route for a full day or mfr. testing with prior CARB/EPA approval	• Real world fleet driver and route for a full day or mfr. testing with prior CARB/EPA approval
Method	◦ MAW Euro VI(d)	◦ TBD
Cold Start	◦ Cold start engine coolant temp. exclusion	◦ Include composite weighting
Exclusions	• Extreme ambient conditions & PEMS checks	• Extreme ambient conditions & PEMS checks
Window size	◦ Work or CO_2 equivalent on an FTP cycle	◦ TBD
Window Validity	◦ Avg window power at or above 10% Power Threshold	◦ All operation
Test Validity	◦ 3 hours valid test data	◦ N/A (all valid operation considered)
Emissions metric	• Work or CO_2 specific	◦ CO_2 specific
Emissions Evaluation	◦ 90th percentile of valid window emissions	◦ 9X% percentile (TBD) of warm valid window emissions ◦ 100th percentile of cold start window emissions
Conformity Factor	◦ $CF_{final} = 1.5$	• $CF_{final} = 1.5$
Pass Criteria	◦ $\frac{e_{nth\ percentile}}{e_{FTP\ std.}} \leq CF_{final}$	◦ $0.14 \times CF_{cold} + 0.86\ CF_{warm} \leq CF_{final}$

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HDIUT: NEXT STEPS

HDIUT Tasks	Estimated Completion
1. Low NO_x Workshop: Rough proposal	Jan 2019
2. Low NO_x Workgroup: window size and emissions metrics investigation by SwRI	Feb 2019
3. Draft proposal	Apr 2019
4. Low NO_x Workshop: Draft proposal Draft regulatory language (2022-2026MY)	May 2019
6. Low NOx Board Hearing	Q1 2020

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COMPLIANCE REPORT CHECKLIST FOR MAW EURO VI (D)

The compliance report for analysis using the moving average window method described in Euro VI(D) must include the following items:

- All on-road testing data already required by HDIUT Testing 40 CFR 86 Subpart T
- Engine families' work and CO_2 on the FTP cycle
- Analyzed window data must include: window length, start of window, end of window, window power, measured window size, window emissions HC, CO, NOx, PM, window validity
- Rank the valid window g/bhp-hr emissions and report the 50^{th}, 90^{th}, and 100^{th} percentile of the criteria pollutants

Appendix 2

CALIFORNIA AIR RESOURCES BOARD

HEAVY-DUTY LOW NOX OMNIBUS PROGRAM WORKSHOP
EWIR AMENDMENTS
JANUARY 23, 2019

EMISSION WARRANTY INFORMATION REPORTING (EWIR) AMENDMENTS FOR MANUFACTURERS OF HEAVY-DUTY ENGINES

EMISSIONS COMPLIANCE, AUTOMOTIVE REGULATIONS AND SCIENCE (ECARS) DIVISION

1

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EWIR OVERVIEW

- Manufacturers are required to track and report warranty claims/failure rates
- Warranty reporting is a critical tool for monitoring and assessing in-use performance
- Manufacturers must take corrective action (typically recalls or extended warranties) when corrective action thresholds are exceeded
- Corrective action plans are reviewed prior to implementation to ensure that they will be successful, meet regulatory requirements, and adequately address the in-use issue

3

PROPOSED AMENDMENTS OBJECTIVES

- Add explicit consequences for not addressing in-use warranty issues in an expeditious manner (already allowed by statute)
  - Complying with warranty reporting and corrective action requirements shall be conditions under which the Executive Order is granted
    - Aligns with certain conditions under which PC, LDT and MDV Executive Orders are granted 40 CFR 86.1848-01 (c)
  - Failure to comply with CCR 2143 (corrective action for high failure rates) and warranty reporting requirements may result in revocation of the Executive Order and the manufacturer may be subject to penalties
  - Future Executive Orders may be called into question (e.g. no carryover allowed) if a manufacturer has a history of not meeting conditions under which Executive Orders are issued

4

PROPOSED LOWER THRESHOLDS

- Lower thresholds for reporting and corrective action:

	Current	Proposed
EWIR	1% or 25 unscreened claims (whichever is greater)	1% or 12 unscreened claims (whichever is greater)
FIR	4% or 50 unscreened claims (whichever is greater)	4% or 25 unscreened claims (whichever is greater)
EIR	4% or 50 failures (whichever is greater)	4% or 25 failures (whichever is greater)
Corrective Action	4% or 50 failures (whichever is greater)	4% or 25 failures (whichever is greater)

To account for small volume engine families

5

PROPOSED CORRECTIVE ACTION REQUIREMENTS

- Recalls shall be required for primary emission control components and computers

  Problematic critical emission control components should be corrected immediately

- Extended warranties shall be considered for other emission-related components
- Other emission-related components with warranty rates >=25% will require recall

  Warranty rates over 25% are indicative of a systemic problem and will require recall regardless of the component

6

PROPOSED NEED FOR CORRECTIVE ACTION WILL BE BASED ON FAILURE RATES

- Manufacturers must attest to an engine family meeting all emission standards and test procedures at the time of certification
- Statutory authority based on HSC 43106 – Each new engine shall be in all material respects, substantially the same in construction as was certified
- CCR 2147 (Demonstration of compliance with Emission Standards) and CCR 2148 (Evaluation of Need for Recall) shall not apply to 2021 MY and newer heavy-duty engine families

Need for corrective action shall be based solely on warranty failure rates

7

PROPOSED ENHANCED WARRANTY REPORTING

- Track and report warranty data throughout the extended warranty period for components for which an extended warranty was issued due to high failure rates, and throughout the warranty reporting period for components replaced under recall

  Will allow CARB to determine whether replacements components are in compliance

- EIRs must include a corrective action implementation date no later than 180 days after the EIR is due

  To ensure that corrective action is taken in a timely manner

8

PROPOSED WARRANTY REPORTING VERIFICATION

- Create more robust warranty reporting verification processes
  - Manufacturers shall retain warranty parts that were analyzed for warranty reports throughout the useful life of the engine family

CARB may evaluate parts to verify warranty reporting

  - Manufacturers shall provide information regarding the number of warranty repairs at each repair station upon the Executive Officer's request

Will aid in verifying warranty reporting and conducting dealer audits

9

PROPOSED CLARIFICATION TO USE GOOD ENGINEERING JUDGEMENT

- HD Test procedures will require manufacturers to use good engineering judgement when investigating failures and generating warranty reports

Currently expected from manufacturers (clarifying)

10

PROPOSED CLARIFYING LANGUAGE/MINOR CHANGES

- Eliminating ambiguity for warranty reporting due dates
- Update contact information for submission of warranty reports

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DATA REQUESTS

- What percentage of warranty claims fall under each warranty?
  - 1. 5 year/100,000 mile warranty
  - 2. Base engine warranty
  - 3. Paid extended warranty
- Emissions data for failed components
  - Test data that quantifies the emissions impact of failed components
- Extended warranty purchase rates, pricing, and coverage descriptions
- Highly encourage manufacturers to share data with CARB
- Data from manufacturers will help better refine EWIR regulations

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Appendix 3

CALIFORNIA AIR RESOURCES BOARD

HEAVY-DUTY LOW NOx PROGRAM

PUBLIC WORKSHOP

JANUARY 23, 2019

PROPOSED DURABILITY DEMONSTRATION PROGRAM FOR ON-ROAD HEAVY-DUTY DIESEL-CYCLE ENGINES

MOBILE SOURCE CONTROL DIVISION

DURABILITY DEMONSTRATION PROGRAM (DDP) - BACKGROUND

- The objective of the certification DDP is to:
  - Demonstrate that each certified engine family meets the applicable emissions standards at the end of its useful life (UL)
  - Demonstrate emission related component durability throughout UL (subject to scheduled maintenance intervals)
- DDP is a certification requirement
- For heavy-duty diesel engines, DDP is currently performed by aging the engine and aftertreatment system (EAS) to a portion of the useful life (≈35-50% UL) on an engine dynamometer
- Since EAS is currently aged to a portion of UL, the deteriorated full UL emissions are estimated by linear extrapolation of emissions data from the DDP

2

NO PROPOSED CHANGES FOR HEAVY-DUTY OTTO-CYCLE DDP

- The following proposals apply only to engine families that are certified through heavy-duty diesel test procedures
- Engine families certified through heavy-duty Otto-cycle test procedures will continue to use the existing procedures to demonstrate full UL durability demonstration. Adjustments to the useful life period will need to be considered.

3

PROPOSED DDP PROCESS

- **Goal**
  - Obtaining Deterioration Factor (DF) values that better reflect real world deterioration for EAS at time of certification
- **Method**
  - Standardizing the DDP Process for 2022 and subsequent model year NEW heavy-duty diesel engine families (does not apply to 2022 model year carryover engine families)
- **Elements**
  - Regenerations prior to emissions tests
  - Break-in Period

  } Applicable to durability & certification engines

  - Standardized Dynamometer Aging Cycles & Accelerated Aftertreatment Aging option
  - Opportunities for validation of durability via in-use and NOx sensor data in 2026+ MY (Alternate Durability Program Concept)

4

REGENERATIONS BEFORE OFFICIAL EMISSIONS TESTS

- New preconditioning procedures to minimize the impacts of auto and manual regenerations on emissions test results
  - Need to assure that emission levels have stabilized prior to an official emissions test
- Manual regenerations
  - If used, report in the certification application or durability test results
  - No emissions test allowed until 40 hours of service accumulation after each manual regen event
- Auto regenerations (includes: soot cleaning, ammonia de-crystallization, sulfur removal, hydrocarbon removal, etc.)
  - No emissions test allowed until 10 hours of service accumulation after each auto regen event

5

BREAK-IN PERIOD

- Initial break-in period is required to assure that emissions are stabilized before an official emissions test is conducted
- Survey of on-road heavy-duty diesel-cycle durability data indicate that the current default 125 hours of break-in period is insufficient for achieving stabilized emissions
- Propose to increase the default break-in period to 300 hours
  - Similar to Tier IV off-road compression-ignition engines
- Manufacturers may propose alternate break-in period as described in §86.004-26(c)(4). Must provide actual emission test results at various intervals to verify that FTP, SET and Low Load Cycle (LLC) stabilized emissions have been reached for each engine family

6

NEED FOR DDP REVISIONS

- Staff believes that current 35-50% of UL method does not fully represent real life component failures and emission deterioration of EAS
- Need to enhance the process for EAS aging
- OBD regulations (adopted Nov. 2018) defined a standardized process for OBD-aging
  - Objective is to obtain similar OBD system response between laboratory aging and real-life in-use aging
- Certification DDP objectives & compliance evaluation process are different:
  - Demonstrate emission related component durability,
  - Estimate expected deterioration of EAS over UL, i.e. develop DFs

7

DDP PROPOSAL

- Goal is to have a program that represents full UL (FUL) EAS aging
- Manufacturers must use standardized DDP process and aging cycles for all certified products
  - For EAS aging on a dynamometer, we propose two possible pathways:
    - Pathway 1 - Use the standardized certification cycles (FTP, SET) for aging
    - Pathway 2 - Use Phase 2 GEM model to create engine aging cycle
    - Select the pathway which yields the highest cycle-average engine power level (CAPL) based on maximum engine power
- An option for using Diesel Aftertreatment Accelerated Aging Cycle (DAAAC*) protocol is proposed for a portion of the durability testing period for HHDD
- Other accelerated aftertreatment aging processes under development may also be considered in lieu of DAAAC (subject to CARB pre-approval)

* https://cleers.org/wp-content/uploads/formidable/3/Bartley_CLEERS2012.pdf

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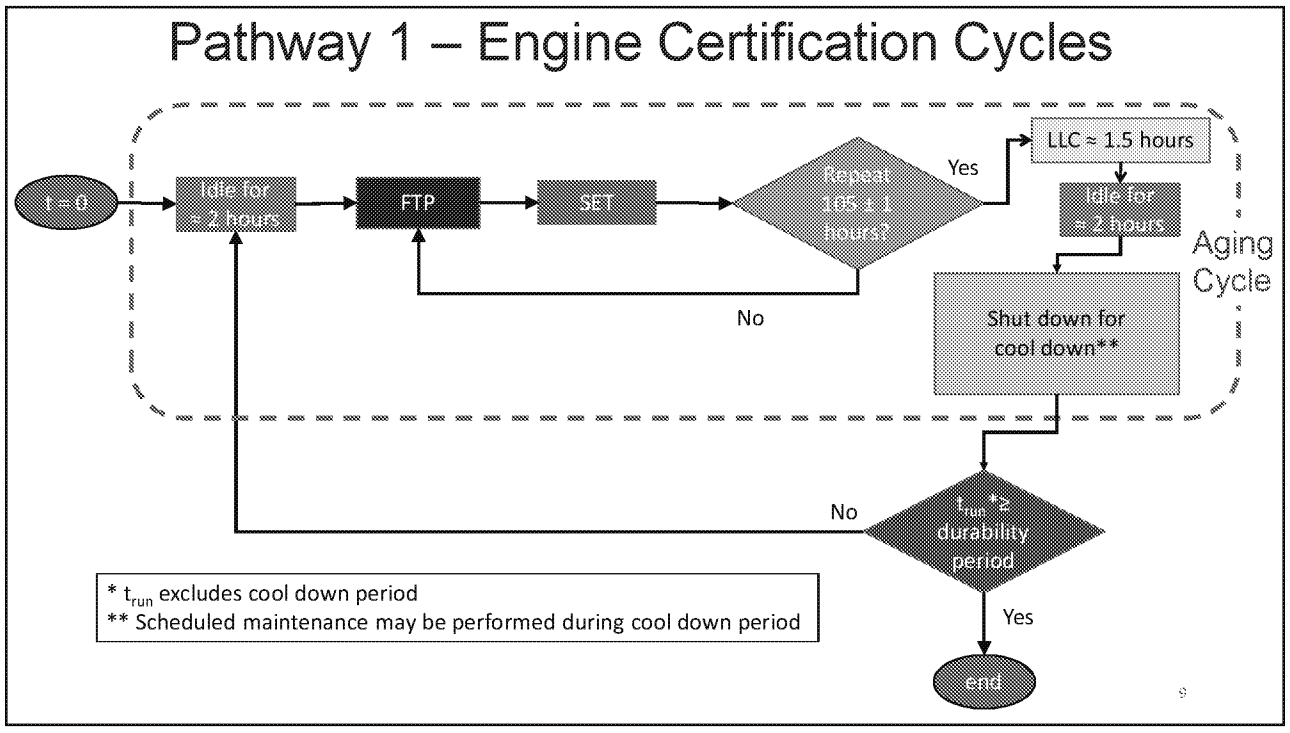
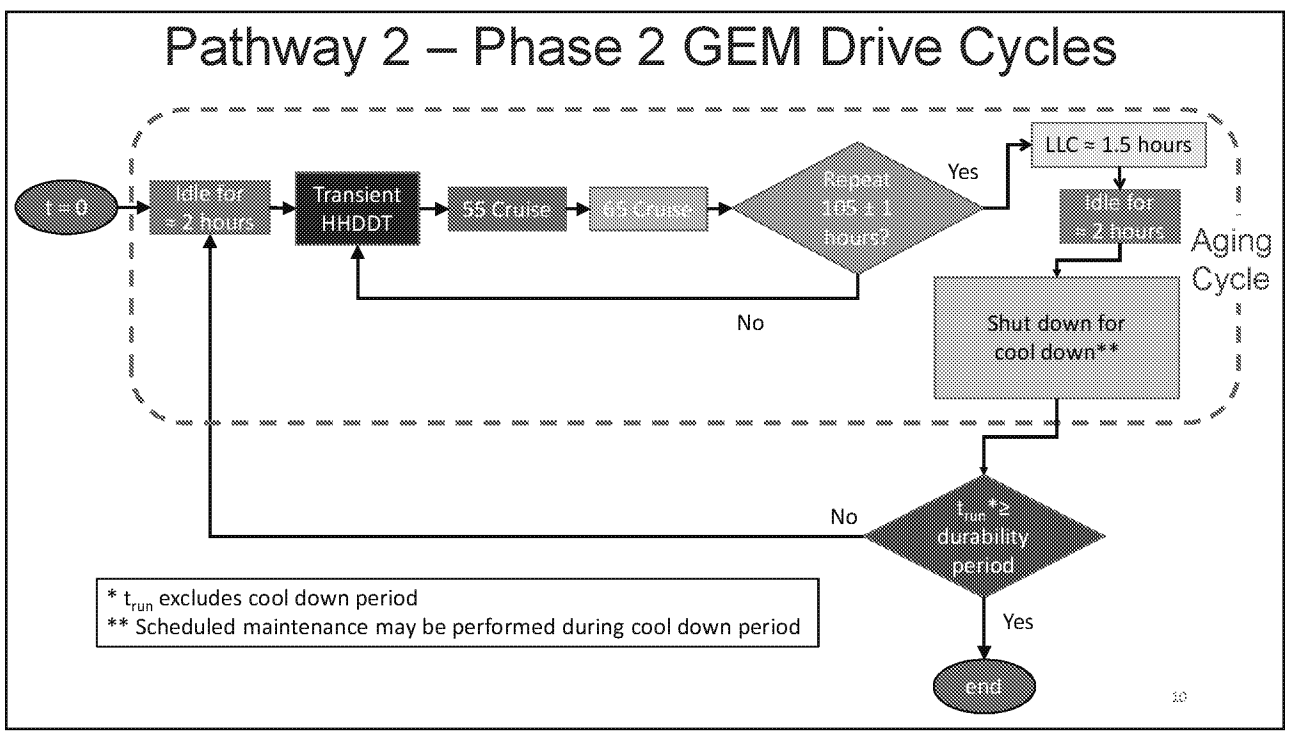
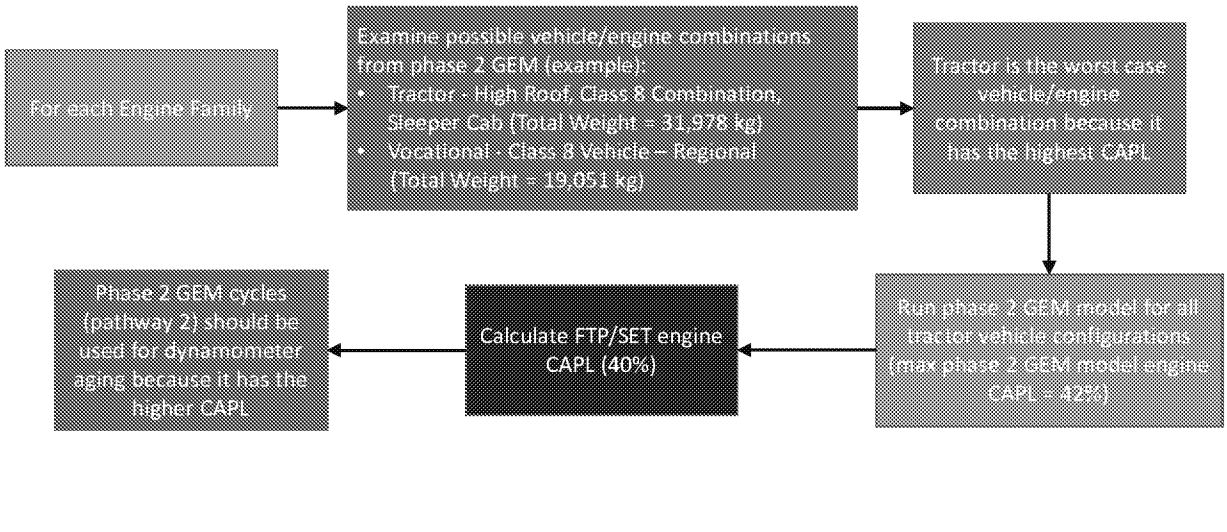

Pathway 1 – Engine Certification Cycles
t = 0
Idle for ≈ 2 hours
FTP
SET
Repeat 105 ± 1 hours?
Yes
No
LLC ≈ 1.5 hours
Idle for ≈ 2 hours
Shut down for cool down**
Aging Cycle
t_{run} * ≥ durability period
No
Yes
end
* t_{run} excludes cool down period
** Scheduled maintenance may be performed during cool down period


Pathway 2 – Phase 2 GEM Drive Cycles
t = 0
Idle for ≈ 2 hours
Transient HHDDT
55 Cruise
65 Cruise
Repeat 105 ± 1 hours?
Yes
No
LLC ≈ 1.5 hours
Idle for ≈ 2 hours
Shut down for cool down**
Aging Cycle
t_{run} * ≥ durability period
No
Yes
end
* t_{run} excludes cool down period
** Scheduled maintenance may be performed during cool down period

Example – Dynamometer Pathway Selection Process (for illustration purpose only)



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PROPOSED DDP SERVICE ACCUMULATION SCHEDULES

Primary Intended Service Class	Current UL (miles)	DDP Procedures
LHDD	110,000	Age EAS on dynamometer to FUL using pathway 1 or 2 cycles **(≈ 2,500* hours)**
MHDD	185,000	Age EAS on dynamometer to FUL using pathway 1 or 2 cycles **(≈ 4,200* hours)**
HHDD	435,000	Two possible options: • Age EAS on dynamometer to FUL using pathway 1 or 2 cycles **(≈ 9,800* hours)**, or • Age EAS on dynamometer for 4,600 hours using pathway 1 or 2 cycles, and then age aftertreatment only using DAAAC for an additional 500-600 hours (equivalent to ½ UL). Age for 300 additional dyno hours **(≈ 5,500* hours)**. This option requires NOx sensor data submittal.

* Service accumulation schedule DOES NOT INCLUDE time required for cool down. Assumes 11 MPH average speed and 1.5 hour duration for LLC (subject to change).

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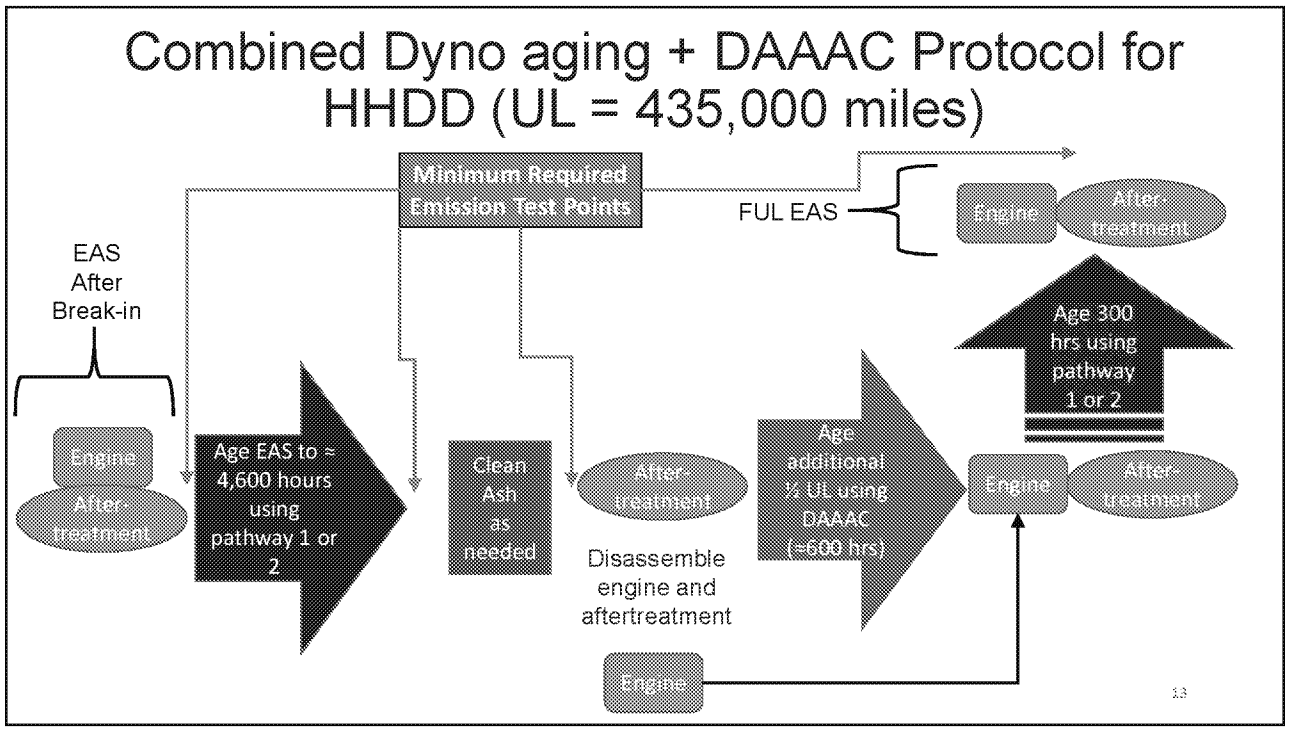

ALTERNATE DURABILITY PROGRAM CONCEPT (2026+ MY)

- CARB is considering an increase to UL for all HD primary intended service classes beyond current values starting with 2026 MY
- By 2026 MY, CARB anticipates that a combination of in-use test data, lab aging data, and NOx sensor reporting may lead to the development of an alternate durability program that relies on submittal of NOx sensor reports combined with a shortened lab aging program
- Manufacturers with high emission related component failure rates may not be eligible to use the accelerated aftertreatment aging option or alternate durability program

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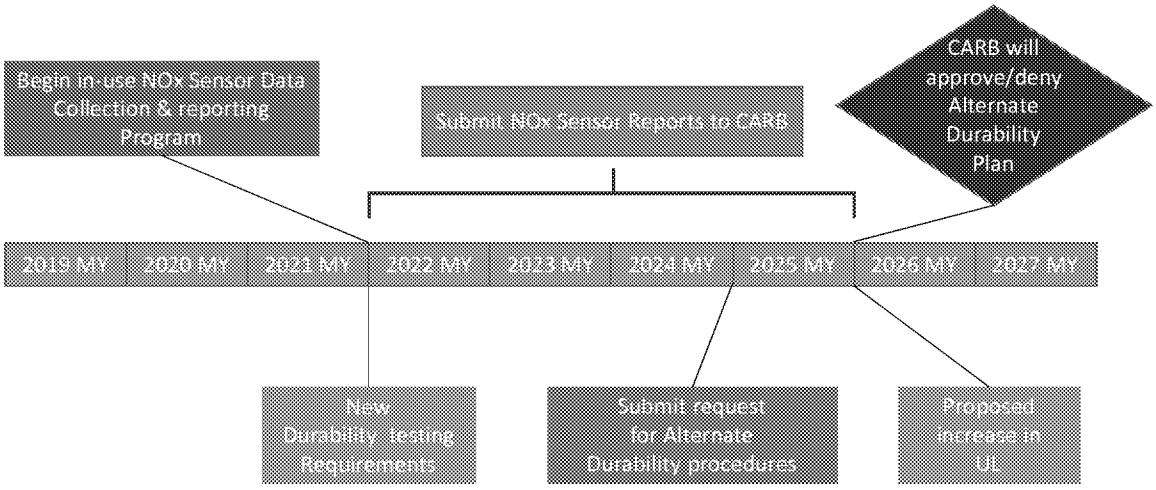
Timeline – Alternate Durability Program Concept



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Appendix 4

CALIFORNIA AIR RESOURCES BOARD

HEAVY-DUTY LOW NOx PROGRAM WORKSHOP

JANUARY 23, 2019

LOW LOAD CYCLE DEVELOPMENT

MOBILE SOURCE CONTROL DIVISION

CALIFORNIA AIR RESOURCES BOARD

OBJECTIVE

- Current engine certification cycles (HD-FTP and RMC-SET):
  - Do not account for sustained low load operations
  - Too short to adequately test for active thermal management of aftertreatement system
- Objective is to develop a new Low Load Cycle (LLC) that:
  - Is representative of real-world urban tractor and vocational vehicle operations that are characterized by low engine loads
  - Has average power and duration adequate for demonstrating that hardware and controls needed to deal with low load challenges are present and functional
  - Has emission standard that balances the need for NOx emission reductions and any associated GHG emission impacts
- Work performed under Stage 2 of the Low NOx Demonstration program by SwRI (with support from NREL)

LOW LOAD CYCLE DEVELOPMENT STEPS

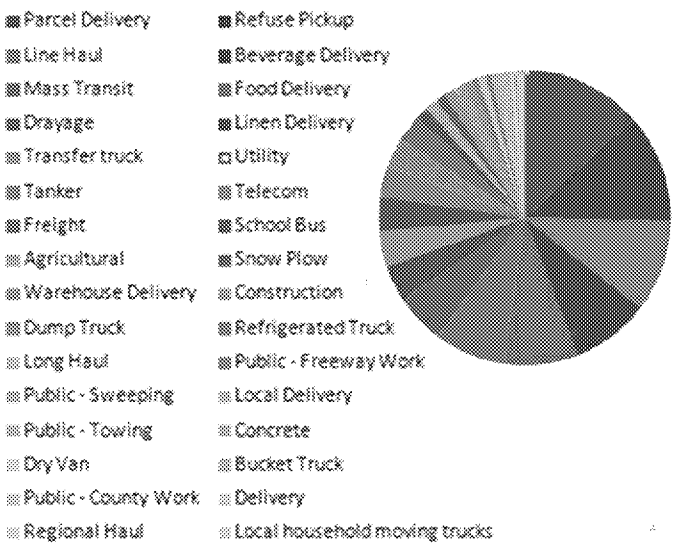
1. Development of Low Load Vehicle Profiles (NREL) ✓
2. Translation of Vehicle-Based Profiles to Engine-Based Ones (SwRI) ✓
3. Testing of Low Load Engine Profiles (SwRI) ✓
4. Development of Candidate Low Load Cycles (NREL / SwRI) ✓
5. Testing of Candidate Low Load Cycles (SwRI) ✓
6. Selection of Final Low Load Cycle (CARB / SwRI) – In Progress

ANALYSIS OF VEHICLE ACTIVITY DATA

Source Datasets

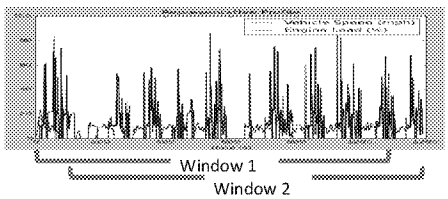
Fleet DNA + CARB HDDV Activity Data

- 751 vehicles
- 25 Locations across the US (predominantly in CA)
- 55 Fleets
- 44 Vocational Designations
- ~600+ GB of raw data

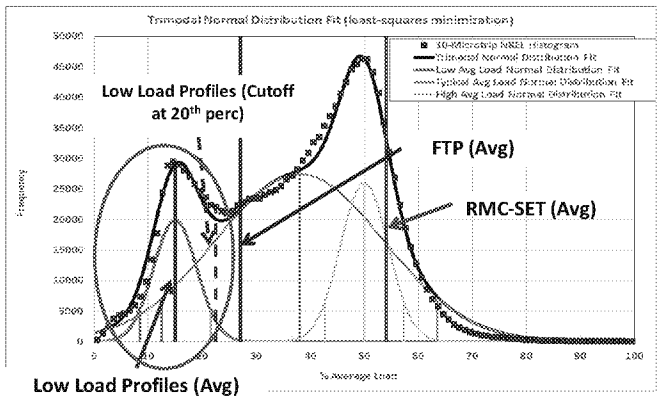


DEVELOPMENT OF LOW LOAD VEHICLE PROFILES

- Data analyzed using moving windows of 10 microtrips

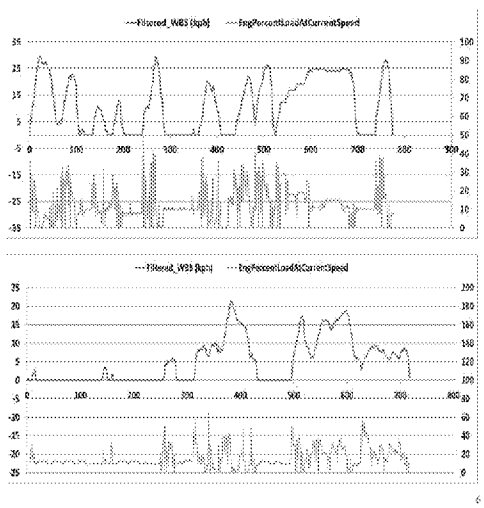


- ~1.25 million windows (profiles) obtained
- Only profiles with average loads below 20% were further considered for constructing the LLC



CLUSTERING AND SELECTION OF REPRESENTATIVE PROFILES

- K-means clustering applied to the population of profiles to identify groups with similar characteristics
  - A total of 3 clusters were identified
- To identify most representative profiles, results for each cluster were ranked based on their distance to cluster center
- Starting with profiles closest to cluster center, profiles examined for behavior and final suitability for testing
- Profiles with outlying behavior removed from list



BASIC EMISSION CONTROL CHALLENGES

- An effective Low Load Cycle will test all three of the following challenges:
  - High Load-to-Low Load Transition
    - Drive to work-site then lower load work or idle period
    - How long can system maintain performance and manage heat during prolonged cool-off?
  - Sustained Low Load
    - Repeated short transients separated by idle (delivery, refuse, transit bus, drayage)
    - Can system maintain heat levels long-term?
  - Low Load-to-High Load Transition
    - Long downhill grade transition to uphill (Tractor)
    - Long idle transition to highway work
    - Can system handle abrupt increases in engine-out emissions?

SUMMARY OF REPRESENTATIVE PROFILES

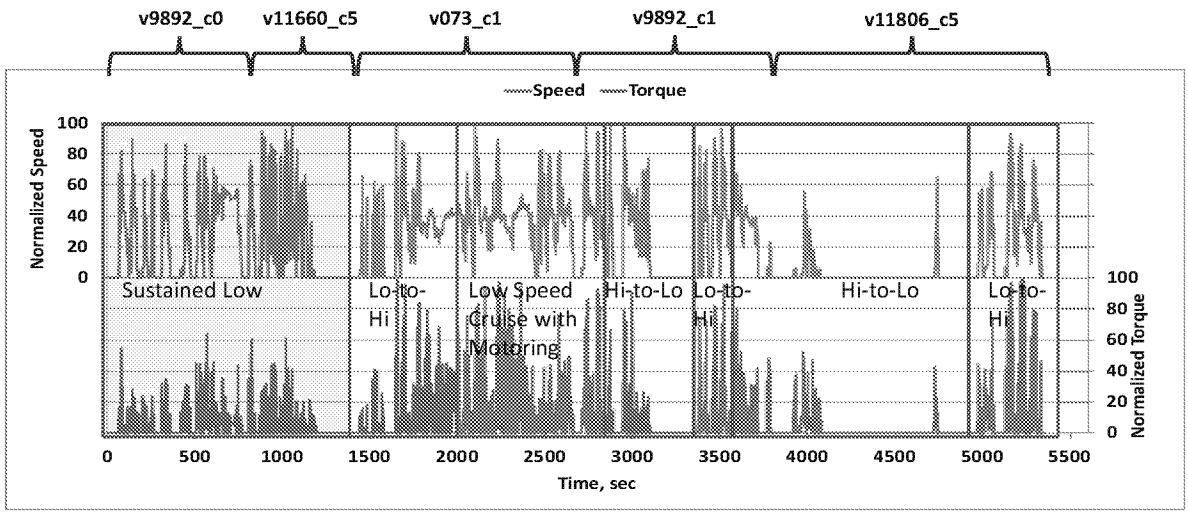
Profile	Vehicle	Cluster	Length	Avg % Speed	Avg % Torque	Repeats in SwRI Test Runs	Class	Chassis	Engine	Trans	Gears	Vocation
1	v9892	0	800	26.9	6.9	4	8	4x2	Volvo D13	AMT	12	Food Service
2	v11660	0	1295	21.4	6.6	3	8	6x4	Mack MP8-415C	MT	13	Drayage
3	v075	0	1130	26.3	7.4	3	8	6x4	Mack MP8-415C	AMT	10	Drayage
4	v11815	1	1949	11.5	8.8	3	8	6x4	Cummins ISX 15	MT	13	Transfer Truck
5	v11646	1	904	15.9	10.7	4	4	4x2	Cummins ISB 6.7	AT	6	Parcel Delivery
6	v073	1	1410	33.8	18.1	3	8	6x4	Mack MP8-415C	AMT	10	Drayage
7	v9892	1	1616	27.0	10.6	3	8	4x2	Volvo D13	AMT	12	Food Service
8	v11660	5	615	16.2	3.5	4	8	6x4	Mack MP8-415C	MT	13	Drayage
9	v11806	5	1810	7.5	6.8	3	8	6x4	Cummins ISX 12	AMT	10	Transfer Truck
10	v11817	5	739	15.3	7.7	4	8	6x4	Cummins ISM 11	AMT	10	Transfer Truck

❖ Load data broadcast by engines not sufficiently accurate for use directly to create engine cycle, so used Phase 2 Greenhouse Gas Emissions Model (GEM) simulation model to translate vehicle-based profiles to engine-based ones

INITIAL CANDIDATE CYCLES

- Five primary types of events were observed in the low load profiles:
  - Sustained low load
  - Long idle
  - Motoring/short idle cooling
  - Post-cooling breakthrough (high load segments)
  - Mid-speed cruise-motoring
- Initial candidate cycles were constructed to include one example of each of the 5 types of events
- Did not always use the entire profile if the key segment could be completed in a shorter time

EXAMPLE CANDIDATE CYCLE



OTHER CONSIDERATIONS

- Preconditioning procedure to bring engine to temperature and warm aftertreatment
  - 1 FTP + 20 min soak
- Longer duration for long idle segment?
  - Not productive, no change in results
- Longer or shorter sustained low load segment?
  - Pro: countermeasure for higher thermal inertia systems
  - Con: longer cycle time
- Longer or shorter mid-speed cruise/motoring segment?
  - Pro: bridges space from rest of LLC to FTP in terms of power, covers upper corner of low load space
  - Con: inclusion does raise overall temperatures, but minor effect, also longer cycle time

FINAL CANDIDATE CYCLES

- LLC Candidate #7 – 90 min
  - 30 min sustained low load segment
  - Retains v073 mid-speed cruise/motoring segment
- LLC Candidate #8 – 81 min
  - 30 min sustained low load segment
  - Shorter v073 mid-speed cruise segment for breakthrough only
- LLC Candidate #10 – 70 min
  - 20 min sustained low load segment
  - Shorter v073 mid-speed cruise segment for breakthrough only

Currently favored by CARB Staff

LLC Candidates – Test Results on Engine E

Candidate	Duration [min]	Conversion efficiency [%]	Engine Out NOx [g/bhp-hr]	Engine Out NOx [g NOx/kg CO2]	Tailpipe NOx [g/bhp-hr]	Tailpipe NOx [g NOx/kg CO2]
#7	90	74	3.2	4.4	0.8	1.1
#8	81	77	2.9	4.1	0.7	0.9
#10	70	69	3.2	4.3	1.0	1.3

PLANNED LLC REQUIREMENTS

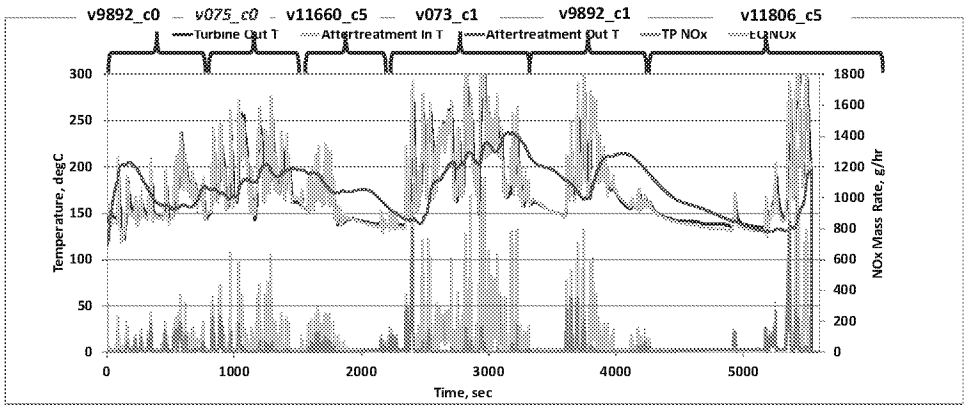
- LLC standard will be based on:
  - SwRI Stages 2 and 3 calibration test results
  - Potential GHG emission impacts
  - Could be a standalone standard or combined with other test requirements
    - e.g., incorporate idle test within the LLC test (to reduce testing burden)
- Conformity factor for LLC and in-use testing requirements:
  - May be same or different, depending on SwRI LLC optimization results
- May include a CO_2 emissions cap
- Preliminary proposal on LLC standard /CO_2 cap: March 2019 workgroup Meeting

CONTACTS

- Kim Heroy-Rogalski, Chief
  Mobile Source Regulatory Development Branch
  Kim.Heroy-Rogalski@arb.ca.gov
  (916) 327-2200
- Stephan Lemieux, Manager
  On-Road Heavy-Duty Diesel Section
  stephan.lemieux@arb.ca.gov
  (626) 450-6162
- Lee Wang, Ph.D., P.E., Air Resources Engineer
  On-Road Heavy-Duty Diesel Section
  Lee.Wang@arb.ca.gov
  (626) 450-6145
  Lead: Low Load Cycle Development, HD Low NOx Demonstration Program

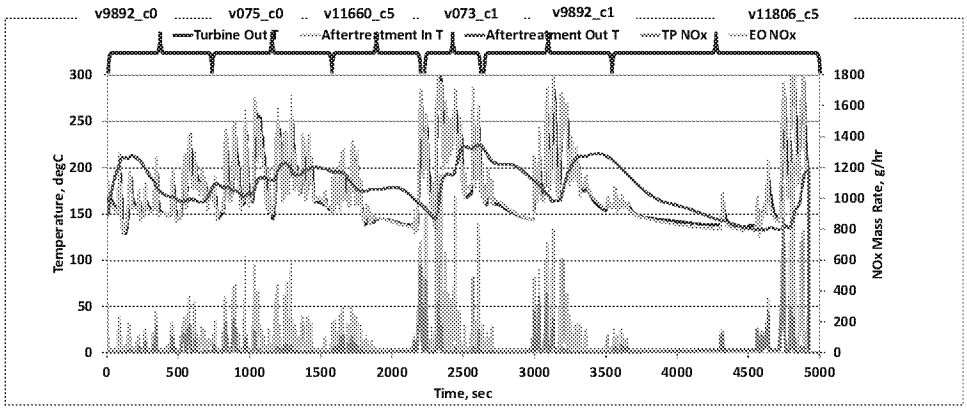
Backup Slides

LLC Candidate 7 – Test Results on Engine E



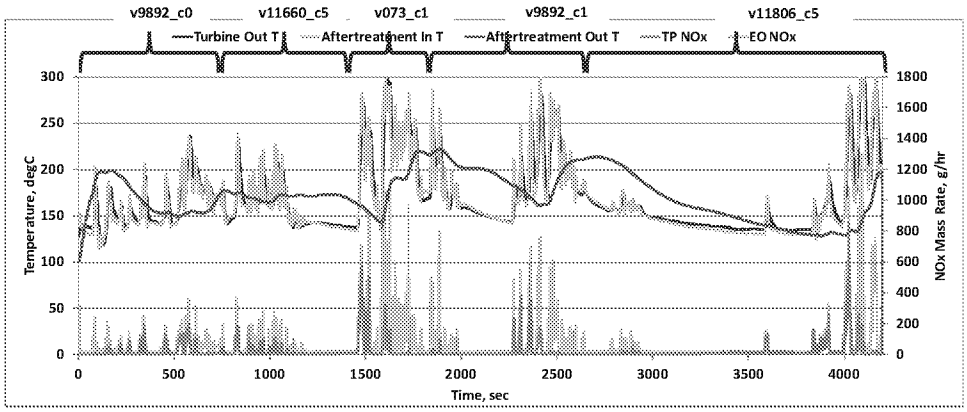
- Overall 74% conversion
- EO NOx (g/hp-hr / g/kgCO2) = 3.2 / 4.4
- TP NOx (g/hp-hr / g/kgCO2 = 0.8 / 1.1

LLC Candidate 8 – Test Results on Engine E



- Overall 77% conversion
- EO NOx (g/hp-hr / g/kgCO2) = 2.9 / 4.1
- TP NOx (g/hp-hr / g/kgCO2 = 0.7 / 0.9

LLC Candidate 10



- Overall 69% conversion
- EO NOx (g/hp-hr / g/kgCO2) = 3.2 / 4.3
- TP NOx (g/hp-hr / g/kgCO2 = 1.0 / 1.3

Message

From: Charmley, William [charmley.william@epa.gov]
Sent: 4/15/2019 6:12:19 PM
To: Grundler, Christopher [grundler.christopher@epa.gov]; Cook, Leila [cook.leila@epa.gov]; Hengst, Benjamin [Hengst.Benjamin@epa.gov]; Haugen, David [haugen.david@epa.gov]; Simon, Karl [Simon.Karl@epa.gov]; steve.cliff@arb.ca.gov; Hebert, Annette@ARB [annette.hebert@arb.ca.gov]; jack.kitowski@arb.ca.gov; Carter, Michael@ARB [michael.carter@arb.ca.gov]; richard.corey@arb.ca.gov; analisa.bevan@arb.ca.gov; mark.fuentes@arb.ca.gov; Bunker, Byron [bunker.byron@epa.gov]; Fuentes, Mark@ARB [mfuentes@arb.ca.gov]; McCarthy, Mike@ARB [mmccarth@arb.ca.gov]; Morris, Desirey@ARB [Desirey.Morris@arb.ca.gov]
Subject: April 15, OTAQ/ARB Senior Leadership Coordination Call - Request for Agenda items
Attachments: ARB-EPA SL Call Agenda, April 15, 2019.docx

Dear all –

Attached, and copied below, is the Agenda for today's call.
Thanks
Bill

Monthly ARB-OTAQ Senior Leadership Coordination Call
Monday, April 15, 2019 (12-1pm Pacific, 3-4pm Eastern)

Call-in number: ph. Conference Line/Code / Ex. 6 Participant Passcode: Conference Line/Code / Ex. 6

Agenda Items

1. EPA update on Marine Diesel Tier 4 Engine Amendment NPRM & Marine distillate fuel sulfur amendment (Charmley – 5 minutes)

2. Highway Heavy-duty NOx rule update (ARB and EPA)

3. Other items

Upcoming Actions/Events of Interest:

- April 29-30 NACAA Spring Membership Meeting, Kansas City (ARB/OTAQ on HD NOx panel)
- May 15-16: STEPS Spring Research Symposium in Davis, CA
- June 24-25: Steve Cliff trip to Ann Arbor, possible visit with OTAQ
- July 9-12 Asilomar Conference on Transportation and Energy, Asilomar, CA
- Dec 10-11 STEPS Fall Symposium & Advisory Board Meeting & Deep Dives

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Message

From: Hebert, Annette@ARB [annette.hebert@arb.ca.gov]
Sent: 4/12/2019 5:37:15 PM
To: Grundler, Christopher [grundler.christopher@epa.gov]; Cook, Leila [cook.leila@epa.gov]; Hengst, Benjamin [Hengst.Benjamin@epa.gov]; Charmley, William [charmley.william@epa.gov]; Haugen, David [haugen.david@epa.gov]; Simon, Karl [Simon.Karl@epa.gov]; Cliff, Steve@ARB [Steve.Cliff@arb.ca.gov]; Kitowski, Jack@ARB [jack.kitowski@arb.ca.gov]; Carter, Michael@ARB [michael.carter@arb.ca.gov]; Corey, Richard@ARB [richard.corey@arb.ca.gov]; Bevan, Analisa@ARB [analisa.bevan@arb.ca.gov]; Fuentes, Mark@ARB [Mark.Fuentes@arb.ca.gov]; Bunker, Byron [bunker.byron@epa.gov]
CC: Fuentes, Mark@ARB [Mark.Fuentes@arb.ca.gov]; mike mccarthy [michael.mccarthy@arb.ca.gov]; Morris, Desirey@ARB [Desirey.Morris@arb.ca.gov]
Subject: RE: Monthly OTAQ/ARB Senior Leadership Coordination
Attachments: Announcement - Allen Lyons - ECCD Division Chief.dotx

Just fyi, we have a new Certification and Compliance Division Chief.

Annette Hébert, Assistant Executive Officer
Southern California Headquarters
California Air Resources Board
(626)450-6150 El Monte
(916)322-3302 Sacramento
annette.hebert@arb.ca.gov

-----Original Appointment-----
From: Stewart.Gwen@epa.gov <Stewart.Gwen@epa.gov> **On Behalf Of** Grundler, Christopher
Sent: Monday, February 5, 2018 5:07 AM
To: Grundler, Christopher; Cook, Leila; Hengst, Benjamin; Charmley, William; Haugen, David; Simon, Karl; steve.cliff@arb.ca.gov; Hebert, Annette@ARB; jack.kitowski@arb.ca.gov; Carter, Michael@ARB; richard.corey@arb.ca.gov; analisa.bevan@arb.ca.gov; mark.fuentes@arb.ca.gov; Bunker, Byron
Cc: Fuentes, Mark@ARB; McCarthy, Mike@ARB; Morris, Desirey@ARB
Subject: Monthly OTAQ/ARB Senior Leadership Coordination
When: Monday, April 15, 2019 3:00 PM-4:00 PM (UTC-05:00) Eastern Time (US & Canada).
Where: C174/Rm 6520 - By telephone: Conference Line/Code / Ex. 6 Access Code: Conference Line/Code / Ex. 6

CONFERENCE NUMBER CHANGE:

To: All California Air Resources Board Staff

From: Richard Corey
Executive Officer

Date: April 12, 2019

Subject: APPOINTMENT OF ALLEN LYONS AS THE CHIEF OF THE EMISSIONS CERTIFICATION AND COMPLIANCE DIVISION

I am pleased to announce the appointment of Allen Lyons as Chief of the Emissions Certification and Compliance Division. In his new role, Allen will oversee CARB's mobile source certification programs, its aftermarket parts programs, in-use compliance for vehicles and engines, and the On-Board Diagnostics (OBD) program. These programs are critical for ensuring that mobile sources sold in California meet the state's world-class standards and requirements with minimal excess emission from the time they are sold through to the point they are retired from service. A major current emphasis within ECCD is verification that the true intended benefits of CARB's certification programs are being realized during the full breadth of actual real world operation, and the undertaking of corrective action efforts as necessary when problems are identified.

Allen has been a part of CARB for over 29 years. He was on the ground floor for the development, implementation, and management of CARB's OBD program for on-road vehicles, and has been directly involved with the program for more than 20 years. He also has previous experience overseeing CARB's new vehicle/engine and in-use programs at the branch chief level, and as Chief of the Mobile Source Operations Division. His duties have drawn him in to being greatly involved in numerous compliance cases with industry over the years. He recently completed his role as California's lead for the Clean Vehicles Working Group established under an MOU with Mexico for cooperation on vehicle emission control programs. Allen has a deep understanding of mobile source emission control strategies and extensive experience and expertise in CARB's broad regulatory programs for light- and heavy-duty vehicles, off-road mobile sources, inspection and maintenance, and remote sensing technology. Allen earned his Bachelor of Science degree in Electrical Engineering from California State University, Fullerton.

Please join me in congratulating Allen and in welcoming him to his new role.

Message

From: Cliff, Steve@ARB [Steve.Cliff@arb.ca.gov]
Sent: 4/11/2019 2:44:13 PM
To: Charmley, William [charmley.william@epa.gov]
CC: Grundler, Christopher [grundler.christopher@epa.gov]
Subject: Re: April 15, OTAQ/ARB Senior Leadership Coordination Call - Request for Agenda items

Will do. I haven't reached out to Jed yet. I'm getting a revised version of the white paper tomorrow, so my plan was to reach out to Jed early next week from NYC once I felt the final version was ready.

Steven S. Cliff, Ph.D.
Deputy Executive Officer
California Air Resources Board

From: Charmley, William <charmley.william@epa.gov>
Sent: Thursday, April 11, 2019 7:20:35 AM
To: Cliff, Steve@ARB
Cc: Grundler, Christopher
Subject: RE: April 15, OTAQ/ARB Senior Leadership Coordination Call - Request for Agenda items

Steve,

Sounds good, thanks for letting me know.

When you are able, can you give Chris and /or I a status update on your outreach to Jed Mandel at EMA Deliberative Process / Ex. 5

Deliberative Process / Ex. 5

We will want to know what is that status of your discussion with Jed when we actually have that meeting. I'll make sure that you, Jack, Mike and Kim know whenever that gets scheduled.

I hope you have safe travels and learn lots at the NY auto shows.

Thanks
Bill

From: Cliff, Steve@ARB <Steve.Cliff@arb.ca.gov>
Sent: Thursday, April 11, 2019 8:36 AM
To: Charmley, William <charmley.william@epa.gov>
Subject: Re: April 15, OTAQ/ARB Senior Leadership Coordination Call - Request for Agenda items

Bill,
I will be en route to the New York auto show on Monday. I'm sorry I will miss this.

Steve

Steven S. Cliff, Ph.D.
Deputy Executive Officer
California Air Resources Board

From: Charmley, William <charmley.william@epa.gov>
Sent: Thursday, April 11, 2019 3:10:27 AM
To: Grundler, Christopher; Cook, Leila; Hengst, Benjamin; Haugen, David; Simon, Karl; Cliff, Steve@ARB; Hebert, Annette@ARB; Kitowski, Jack@ARB; Carter, Michael@ARB; Corey, Richard@ARB; Bevan, Analisa@ARB; Fuentes, Mark@ARB; Bunker, Byron; Fuentes, Mark@ARB; McCarthy, Mike@ARB; Morris, Desirey@ARB
Subject: April 15, OTAQ/ARB Senior Leadership Coordination Call - Request for Agenda items

Dear all –

Our April ARB/OTAQ leadership coordination conference call is scheduled for next week on Monday, April 15 from 12-1 pacific time, 3-4 east coast time.

This is a request for Agenda items. I have 2 topic I would like to have on the Agenda which I listed below.

In addition, at the recent EPA Mobile Source Technical Review Subcommittee meeting in Washington, D.C., OTAQ gave an overview of topics on our regulatory agenda. I have attached that, in case any of the actions in the list are items that ARB would like to gain additional information on.

If I could receive any suggested agenda items on Monday by 10am pacific/1pm eastern that would be great – I will incorporate it into the agenda and send around a final version.

Thanks
Bill

DRAFT – Agenda items:

Deliberative Process / Ex. 5

OTAQ Regulatory Outlook

Mobile Source Technical Review Subcommittee Meeting

April 2, 2019

Presented by Bill Charmley, EPA/OAR/OTAQ

Topics

- Regulatory Actions
- Pending Litigations
- Major Studies
- Possible Future Rulemakings

Regulatory Actions: On-road Vehicles & Engines

Action	Description	Milestone Targets
The Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Passenger Cars and Light Trucks. 2060-AU09	Rulemaking to revise MY2021 – MY2026 vehicle GHG standards, possible changes to California vehicle waiver	NPRM Issued August 2018 Final Rule in 2019
Cleaner Trucks Initiative	Rulemaking to revise EPA emission standards for highway heavy-duty engines & vehicles	NPRM in 2020
Vehicle Test Procedure Adjustments for Tier 3 Test Fuel. 2060-AT21	Adjustments to EPA GHG and NHTSA CAFE test procedures to account for change to Tier 3 gasoline certification test fuel	NPRM currently under OMB-led interagency Review

Regulatory Actions: On-road Vehicles & Marine Diesel Engines

Action	Description	Milestone Targets
Light-Duty Vehicle GHG Program Technical Amendments. 2060-AT75	Action to correct errors in EPA regulations from program promulgated in 2012.	NPRM issued October 2018 Final Rule expected in 2019
Amendments Related to Marine Diesel Engine Emission Standards. 2060-AU30	Action to consider amending regulatory schedule for smallest power category of Tier 4 marine standards to provide additional lead time or other accommodations. May include fuel reg. amendment to allow distribution of 5,000 ppm S distillate marine fuel in the U.S., consistent with IMO 2020 std.	NPRM expected in 2019 FRM also possibly in 2019
Improvements to Vehicle Design Criteria for Dual-Fueled Natural Gas Vehicles. 2060-AU31	Action to consider changes to dual-fuel natural gas design criterial in existing EPA regulations. Same issues also under consideration in the SAFE NPRM. May be consolidated with SAFE FRM.	TBD

Regulatory Actions: Fuels

Action	Description	Milestone Targets
2020 Renewable Fuel Volume Annual Standards Rule.	Rulemaking to put in place the renewable fuel obligations for the 2020 Calendar Year.	NPRM expected late May/early June 2019 Final Rule expected Nov 30, 2019
Renewable Fuel Standard Program Modification of Applicable Volume. (**"Reset" Rule)** 2060-AU28	Rulemaking to revise the renewable fuel volumes specified in the statute for 2020-2022	NPRM expected late Summer 2019
E15 RVP Waiver and RIN Market Reform Rule. 2060-AU34	Rulemaking to extend the 1-psi RVP waiver currently applicable to E10 to also apply to E15 - proposing that E15 is substantially similar to E10 cert fuel. Rulemaking to put in place various RIN market reforms to prevent potential RIN market manipulation	NPRM signed 3/19 FRM expected May 31, 2019

Regulatory Actions: Renewable Fuels Program

Action	Description	Milestone Targets
Fuel Regulatory Streamlining Rule. 2060-AT31	Rulemaking to rewrite all of our Part 80 fuel regulations (other than RFS) to be streamlined, easier to understand, and up-to-date	NPRM Fall 2019
2016 Remand	Action to respond to the D.C. Circuit decision that EPA inappropriately lowered the 2016 RFS standards by an inappropriate use of "inadequate domestic supply"	TBD – may occur with 2020 RVO Rule
Renewables Enhancement and Growth Support (REGS) Rule	Rulemaking to allow biointermediates under RFS, put in place standards for higher level ethanol blends, new RFS pathways, seek comment on regulations to allow generation of RINs for renewable electricity, and put in place a number of other technical amendments to RFS.	NPRM proposed Nov. 2016 Final Rule TBD

Regulatory Actions: "Long Term" via Fall Reg. Agenda

Action	Description	Milestone Targets
Control of Air Pollution From **Aircraft and Aircraft Engines: Proposed GHG Emissions Standards** and Test Procedures. 2060-AT26	EPA's 2016 endangerment and cause or contribute findings obligates EPA under section 231 of the Clean Air Act to set emission standards applicable to GHG emissions from aircraft engines. This action would fulfill EPA's obligation, and take into consideration ICAO's 2017 international CO_2 stds.	Long-term Action
Repeal of Emission Requirements for **Glider Vehicles, Glider Engines, and Glider Kits**. 2060-AT79	Reconsideration of EPA requirements established in a 2016 rule. This action re-considers if EPA has authority under the CAA to establish requirements for glider kits, glider engines, and glider vehicles.	NPRM published Nov. 2017 Final Rule: Long-term Action
Endangerment Finding for **Lead Emissions From Piston-Engine Aircraft** Using Leaded Aviation Gasoline. 2060-AT10	EPA would make make a determination, under section 231 of the Clean Air Act, as to whether lead emissions from aircraft operating on leaded fuel cause or contribute to air pollution which may reasonably be anticipated to endanger public health or welfare.	Long-term Action

Major Studies

Action	Description	Milestone Targets
Coastal Marine Mode Shift Study	Study in response to request from Congress. Will examine the potential for transportation mode shift in coastal marine transportation markets as a result of compliance with the North American Emission Control Area fuel sulfur limits. https://www.epa.gov/regulations-emissions-vehicles-and-engines/study-impacts-compliance-eca-fuel-sulfur-limits-us	Interim report completed February 2018 Stakeholder workshop held July 2018 Final study due to Congress end of FY2020
RFS Air Quality Anti-backsliding Study	Carry out a study on the air quality impacts of RFS volumes as required by Section 211(v) of the CAA	Draft proposed Consent Decree would establish deadline of March 30, 2020; public comment on proposed CD closed March 25, 2019

Additional RFS Actions, including Pending Litigation and Petitions

- **Small refinery exemptions for 2018**

- **Numerous ongoing litigation and notices of intent to sue from multiple parties on many aspects of the program, including but not limited to:**
  - 2017, 2018, 2019 Annual standards
  - Point of Obligation for the RFS standards
  - Small Refinery Exemptions
  - RINs for renewable electricity (eRINs)
  - Endangered Species Act Compliance

- **Numerous petitions and other requests on many aspects of the program, including but not limited to:**
  - Waiver of the 2018/19 standards
  - Revision of the annual percent standards to account for small refinery exemptions
  - Aggregate compliance approach for feedstocks from existing agricultural lands
  - New Pathways and Facility Specific Pathways
  - Treatment of mixed feedstocks, corn kernel fiber, "wastes", and others
  - Qualification of various sources of forestry products

Possible Future Actions

- **Highway Heavy-duty Engine & Vehicle Technical Amendments**
  - Vehicle and engine companies have discussed with EPA several issues that should be addressed prior to the start of Model Year 2021
- **Reconsideration of EPA CO_2 Standard for Highway Trailers**
  - Reconsideration of EPA CO_2 standards established for certain types of trailers established in 2016 Final Rule in response to Petition for Reconsideration from Trailer Industry
- **Aircraft Engine Particulate Matter Standards**
  - A possible future EPA action, as a result of the adoption in Feb. 2019 by ICAO of PM standards
- **Locomotive Emission Standards Petition**
  - Outstanding 2016 petition for rulemaking from San Joaquin Valley Air Pollution Control District
- **Beyond Land-based Nonroad Diesel Tier 4 Program**
  - U.S. engine industry has asked EPA to consider updating Tier 4, to consider elements in the European Stage 5 program

Appointment

From: abby.estebat@arb.ca.gov [abby.estebat@arb.ca.gov]
Sent: 3/27/2019 10:02:31 PM
To: Cliff, Steve@ARB [Steve.Cliff@arb.ca.gov]; Kitowski, Jack@ARB [jack.kitowski@arb.ca.gov]; Carter, Michael@ARB [michael.carter@arb.ca.gov]; Heroy-Rogalski, Kim@ARB [kim.heroy-rogalski@arb.ca.gov]
CC: Galgani, Kelcie@ARB [Kelcie.Galgani@arb.ca.gov]; White, Shannon@ARB [Shannon.White@arb.ca.gov]; Nelson, Brian [nelson.brian@epa.gov]; Charmley, William [charmley.william@epa.gov]; Grundler, Christopher [grundler.christopher@epa.gov]; Sargeant, Kathryn [sargeant.kathryn@epa.gov]; Robertson, Bill@ARB [bill.robertson@arb.ca.gov]; Estebat, Abby@ARB [abby.estebat@arb.ca.gov]; Hebert, Annette@ARB [annette.hebert@arb.ca.gov]; ARB MSCD Meetings And Events [600.mscdcal.ARB@arb.ca.gov]

Subject: (E) Coordinate with USEPA Leadership on HD NOx
Attachments: Draft - Agenda for March 28 2019 ARB-OTAQ meeting_revD-for JAck.docx; Principles-kh-cb-KG.docx
Location: CR 620 / Call-In **Conference Line/Code / Ex. 6**

Start: 3/28/2019 4:00:00 PM
End: 3/28/2019 11:00:00 PM
Show Time As: Tentative

Recurrence: (none)

Please see attachments.

Date: **Thursday, March 28, 2019**
Time: **9:00 a.m. – 4:00 p.m.**
Place: **CR 620 / Call-In**

Conference Call Information

Call In Phone Number: **Conference Line/Code / Ex. 6**
Passcode: Conference Line/Code / Ex. 6

Meeting Purpose

Coordinate with USEPA Leadership on HD NOx.

Attendees

Steve Cliff, DEO
Jack Kitowski, DC
Mike Carter, ADC
Kim Heroy-Rogalski, BC

External Attendees

Brian Nelson, USEPA
Bill Charmley, USEPA
Chris Grundler, USEPA

CARB Contact

Sam Gulde
Mobile Source Control Division
916.323.2966
samantha.gulde@arb.ca.gov

Appointment

From: Nelson, Brian [nelson.brian@epa.gov]
Sent: 3/26/2019 3:43:14 PM
To: Grundler, Christopher [grundler.christopher@epa.gov]; Laroo, Chris [laroo.chris@epa.gov]

Subject: FW: Social Event with USEPA Staff
Location: Delta King The Pilothouse

Start: 3/28/2019 1:00:00 AM
End: 3/28/2019 4:00:00 AM
Show Time As: Tentative

-----Original Appointment-----
From: Galgani, Kelcie@ARB <Kelcie.Galgani@arb.ca.gov>
Sent: Wednesday, February 27, 2019 1:37 PM
To: Galgani, Kelcie@ARB; Heroy-Rogalski, Kim@ARB; Kitowski, Jack@ARB; Cliff, Steve@ARB; Carter, Michael@ARB
Cc: Robertson, Bill@ARB; Nelson, Brian; Hebert, Annette@ARB
Subject: Social Event with USEPA Staff
When: Wednesday, March 27, 2019 6:00 PM-9:00 PM (UTC-08:00) Pacific Time (US & Canada).
Where: Delta King The Pilothouse

Message

From: Grundler, Christopher [/O=EXCHANGELABS/OU=EXCHANGE ADMINISTRATIVE GROUP (FYDIBOHF23SPDLT)/CN=RECIPIENTS/CN=D3BE58C2CC8545D88CF74F3896D4460F-GRUNDLER, CHRISTOPHER]
Sent: 4/29/2019 10:41:13 PM
To: Richard Corey [richard.corey@arb.ca.gov]; Steve.Cliff@arb.ca.gov
Subject: Fwd: New Report Highlights Major Concerns With Trump GHG Vehicle Emissions Proposal
Attachments: FINALPRESSRELEASE.docx; ATT00001.htm; FINALGHGREPORT.PDF; ATT00002.htm

FYI, this just came to me. Richard and I recently spoke about Deliberative Process / Ex. 5

Deliberative Process / Ex. 5

Chris

Christopher Grundler, Director
Office of Transportation and Air Quality
U.S. Environmental Protection Agency
202.564.1682 (Washington DC)
734.214.4207 (Ann Arbor MI)
Personal Matters / Ex. 6 mobile)
www.epa.gov/otaq

Begin forwarded message:

> **From:** Bill Becker <bbecker744@comcast.net>
> **Date:** April 29, 2019 at 5:19:47 PM EDT
> **To:** "Grundler.Christopher@epamail.epa.gov" <Grundler.Christopher@epamail.epa.gov>
> **Subject: New Report Highlights Major Concerns With Trump GHG Vehicle Emissions Proposal**
>
> Chris—fyi
>
> I am happy to provide you with our report, released today, on the impacts of the Trump proposal to weaken vehicle GHG emissions standards. The report, *The Devastating Impacts of the Trump Proposal to Roll Back Greenhouse Gas Emissions Standards*, analyzes the rule's non-GHG emissions impacts, including smog-forming emissions, fine particles, and air toxins. Our "untold story" concludes that 1) up to 32,000 people could die prematurely and millions more get sick, 2) state and local agencies' compliance with the Clean Air Act will be severely undermined, and 3) businesses will have difficulties expanding their operations.
>
> I have attached a copy of the report and a press release and include a link to the report below.
>
> Feel free to contact me if you have any questions.

Bill Becker
(Former Executive Director of the National Association of Clean Air Agencies)

https://documentcloud.adobe.com/link/track?uri=urn%3Aaaid%3Ascds%3AUS%3A72b78935-2ee6-4341-a986-8631c70f3505

Bill Becker
bbecker744@comcast.net
301-806-6111

Message

From: Grundler, Christopher [/O=EXCHANGELABS/OU=EXCHANGE ADMINISTRATIVE GROUP (FYDIBOHF23SPDLT)/CN=RECIPIENTS/CN=D3BE58C2CC8545D88CF74F3896D4460F-GRUNDLER, CHRISTOPHER]
Sent: 4/23/2019 10:34:37 PM
To: Steve.Cliff@arb.ca.gov
Subject: Fwd: EMA??

FYI

Christopher Grundler, Director
Office of Transportation and Air Quality
U.S. Environmental Protection Agency
202.564.1682 (Washington DC)
734.214.4207 (Ann Arbor MI)
Personal Matters / Ex. 6 (mobile)
www.epa.gov/otaq

Begin forwarded message:

> **From:** "Charmley, William" <charmley.william@epa.gov>
> **Date:** April 23, 2019 at 6:31:45 PM EDT
> **To:** "Grundler, Christopher" <grundler.christopher@epa.gov>
> **Subject: Re: EMA??**
>
> I went only for the first hour, and I took about 30 to 40 minutes explaining why we need ARB at these technical meetings, and that is our plan going forward.
>
> I don't have anyone from EMA (Tim French or Matt Spears) or any of the members
>
> **Deliberative Process / Ex. 5**
>
> There were a few more thoughts on this I have and I can catch up with you tomorrow.
>
> I don't know how the actual meeting went with EMA, I had never planned on going at all, and I only went for the first hour because of this issue regarding CARB participation
>
> Thanks
> Bill
>
> Sent from my iPhone
>
> On Apr 23, 2019, at 6:15 PM, Grundler, Christopher <grundler.christopher@epa.gov> wrote:
>
> ---
> Christopher Grundler, Director
> Office of Transportation and Air Quality
> U.S. Environmental Protection Agency

202.564.1682 (Washington DC)
734.214.4207 (Ann Arbor MI)
Personal Matters / Ex. 6 (mobile)
www.epa.gov/otaq

Appointment

From: Grundler, Christopher [/O=EXCHANGELABS/OU=EXCHANGE ADMINISTRATIVE GROUP (FYDIBOHF23SPDLT)/CN=RECIPIENTS/CN=D3BE58C2CC8545D88CF74F3896D4460F-GRUNDLER, CHRISTOPHER]
Sent: 4/17/2019 10:30:20 AM
To: Wang, Lee@ARB [Lee.Wang@arb.ca.gov]

Subject: Declined: CARB Low NOx Workgroup Meeting
Location: Exc (AN1)

Start: 4/25/2019 5:00:00 PM
End: 4/25/2019 7:00:00 PM

Recurrence: (none)